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COASTAL ACCRETION AND EROSION IN SOUTHWEST WASHINGTON

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COASTAL ACCRETION AND EROSION
IN
SOUTHWEST WASHINGTON

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ABSTRACT

Approximately 100 years of historical shoreline changes on the coastal beaches of Southwestern Washington have been mapped, and the rates of erosion and/or accretion have been calculated. These data show that, in general, the Washington coastline has been prograding since the turn of the century. Notable exceptions to this general accretional pattern occur on the spits abutting Willapa Harbor, especially Cape Shoalwater, and on the entire beach north of Copalis Head. More recently the area south of the South Jetty has become erosional.

The various factors that affect the erosion-accretion rates are considered in light of a sand budget. As the sand enters the longshore drift system from the Columbia River and is moved northward by seasonally reversing currents, its volume is diminished by bay entrapment in Willapa and Grays Harbor, by beach accretion, and by losses to the offshore. The erosion north of Copalis Head is probably due to the lack of sand in the system to nourish these beaches.

Projections of recent changes in the shoreline are used to construct a shoreline map for the year 2000.

Man-induced dune modifications are considered in the last section of this report. On the Long Beach Peninsula, decreased amounts of eolian sand accreting on the seaward slopes of the primary dune are related to sand removal activities and perhaps to recreational vehicle traffic. It is observed that removal of the primary dune by landowners makes their dwellings considerably more vulnerable to destruction by storm waves and subjects them to increased quantities of windblown sand.

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Setting

The beaches of Southwestern Washington are composed of a single, continuous sand body that stretches northward from the Columbia River for a distance of about 60 miles (Figure 1). Although the landward edge of this sand sheet is interupted by Grays Harbor and Willapa Harbor, its continuity is maintained offshore.

Studies by Ballard (1964) show the dominant source of sand is the Columbia River and that the sand is moved northward by a seasonally reversing longshore currents. These currents are wave generated and move the sand northerly in the winter and southerly in the summer. Because the northerly component of this current system is driven by the high energy winter waves, as compared to the lower energy southerly waves, the predominant drift direction is northerly.

The seasonality of the longshore drift is matched by the seasonality on the beaches themselves. The high energy, short period winter waves draw the sand from the exposed portions of the beaches making them steep and narrow. The summer waves push the sand back on to the beaches and they become wider and flatter.

Thus the beaches of the Washington coastline represent the edge of a sand body that is continuously moving northward (with a lesser southward component) from its source, the Columbia River. As the sand moves north, its volume is diminished; by entrapment in the estuaries on the landward edge, by accretion to the existing beaches, and draining down the several prominent submarine canyons that intersect the Washington continental margin. So by the time the sand reaches the Copalis Rocks, there is not enough to produce the wide accretional beaches typical of Pacific County. From Copalis Rocks north, the sea cliffs

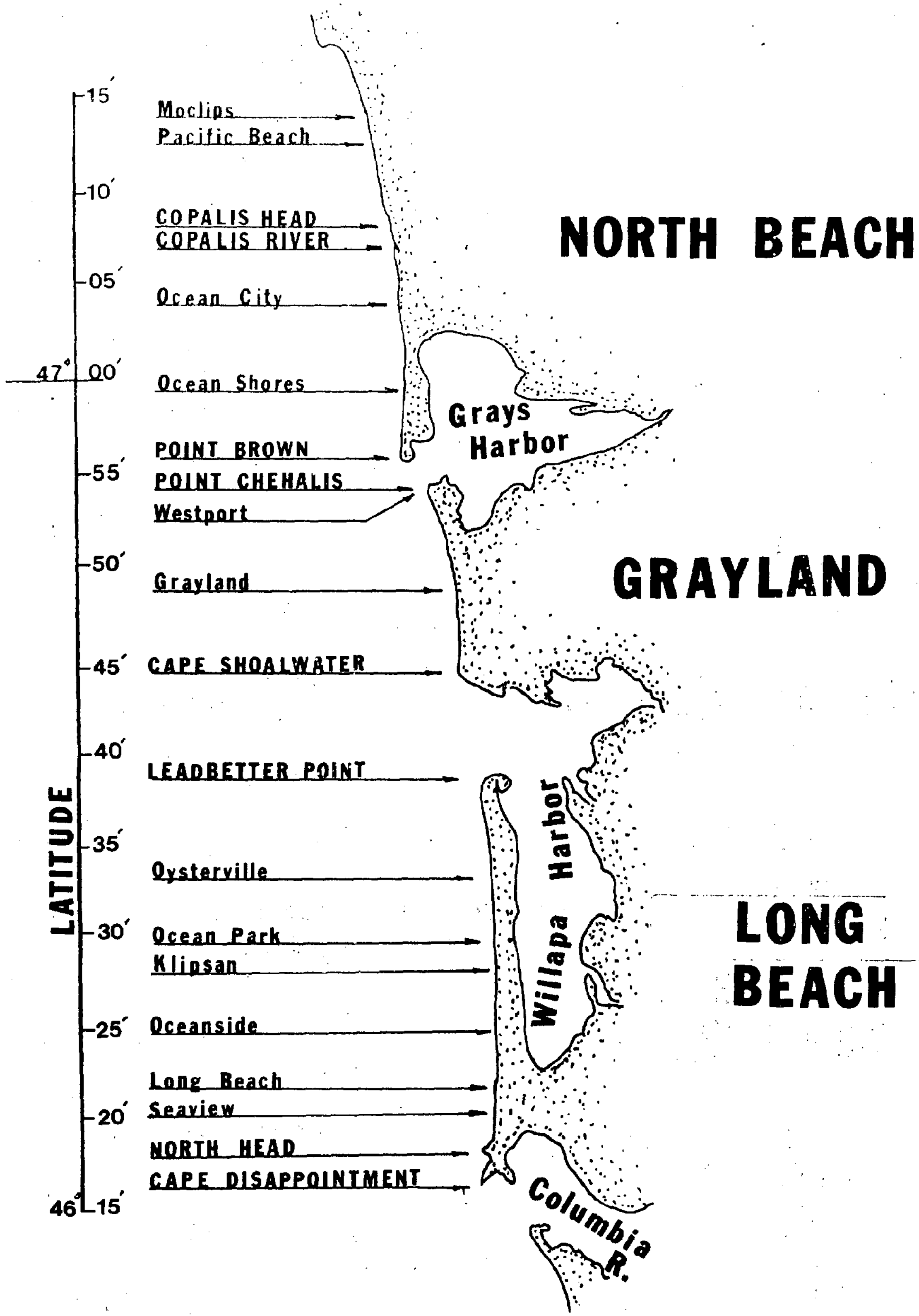

Figure 1. Location Map

abut the high tide zone and the shoreline is erosional. The beaches of Grays Harbor and Pacific Counties then, are part of an extremely complex, dynamic system that moves the sand along the coast.

Purpose

It is the purpose of this report to describe approximately 100 years of changes in the shorelines, and with this historical prespective, reflect on some of the factors that may have been responsible for the observed changes.

Procedure

The primary data used to denote changes in the shoreline were U.S. Coast and Geodetic Surveys, Army tactical mapping, U.S. Army Corps of Engineers Condition reports, aerial photography, and Washington State Department of Fisheries beach profiles. The older mapping done by the U.S. Coast and Geodetic Survey was most useful, although there were troublesome datum changes required to make the maps conform with the modern 1927 North American Datum used on the more recent maps. Modern shorelines were mapped using aerial photography. All the maps and sources used in this report appear in Appendix A.

Many modern maps, like the U.S. Geological Survey Quadrangle Sheets, rely on U.S. Coast and Geodetic Survey Navigational Charts for their hydrography, including the shoreline. These U.S. Coast and Geodetic Survey charts are accurate for navigation, but since the shoreline is not of much significance (i.e., one does not normally drive vessels there), they are the least accurate part of the map. Furthermore, annual charts issued do not mean annual surveys of the shoreline, so it is entirely possible to have old shoreline on a new map.

In 1951, the Washington State Department of Fisheries started surveying selected areas of the beaches, in conjunction with their razor clam sampling program. These surveys measure the beach profiles from established reference points. The locations and elevations of these points were originally determined by tying them to available bench marks. Generally, the areas are surveyed twice a year, once in the late summer (August) and again in the early fall (October). The same profile is surveyed bi-annually, but different profiles, within the same general area, are surveyed on different years. These surveys constitute the most precise data avilable over a long time span, partly because they remove the seasonality factor by surveying at the same time of each year.

The maps in this report show the shoreline at the approximate high tide line. This designation is deliberately vague. The often-used designation of "mean high water" (approximately a +8-foot tide) or "mean higher high water" (approximately a +9.3-foot tide) lose their meaning when compared with older surveys done at "high tide." Furthermore, the aerial photomapping is commonly based on some geomorphological feature (like the dry-sand/wet-sand boundary) whose relationship to actual elevations is vague at best. These problems, coupled with the inaccuracies attendant to datum changes, scale changes, and non-linear reproductions all tend to reduce the amount of precision.

In order to overcome some of the problems inherent in comparing many different kinds of mapping, relatively long time periods (i.e., 20 years or greater) were used. Of course, where consistent mapping on shorter time periods was available, such as the U.S. Army Corps of Engineers Condition Surveys and the Fisheries data, shorter time periods were used. It is possible that a series of bad winter storms in one year could erode the beach and yet this erosion be masked by a longer term accretional phase. Therefore, the area where the erosional damage occurred would be listed as accretional.

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16. Abstracts

Approximately 100 years of historical shoreline changes on the coastal beaches of southwestern Washington have been mapped, and the rates of erosion and accretion have been calculated. Indications are that the coastline has been extending seaward since the turn of the century. Notable exceptions occur on the spits abutting Willapa Harbor, and the entire beach north of Copalis Head.

The factors that affect the erosion-accretion rates are considered in light of a sand budget. Projections of recent changes in the shoreline are used to construct a shoreline map for the year 2000.

Man-induced dune modifications are also considered, and dune-stablization methods are explored.

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Dunes

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Southwest Washington

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages
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This report discusses long-term trends and does not consider the seasonal variations in the beach profiles which, in some years, may be greater than the annual changes. For example, the Washington State Department of Fisheries data show an August to October horizontal change in the position of the +8.0-foot elevation that ranges up to 100 feet. And this represents only a portion of the maximum possible seasonal changes in the profiles.

In this report the shoreline precision is approximately $\pm$ 100 feet.

EROSION-ACCRETION PATTERNS AND RATES

Long Beach Peninsula

Mapping and photography on the Long Beach Peninsula was available for the years 1871-73, 1926, 1936, 1948, 1955, and 1977. The shoreline for each of these years is plotted on Figure 2, and the annual rates of change (erosion or accretion) are shown in Appendix B. A pattern of 106 years of accretion is clearly displayed in the area adjacent to North Head. The over-all rate at 46° 19' north latitude is approximately 20 feet per year. To the north along the peninsula, the shorelines become confused and crisscross one another. At the northerly limits of the mapping (46° 36'), it appears that the beach was generally erosional from the 1870's to about 1955, and from 1955 to 1977, the beach was accretional. Indeed, the entire Long Beach Peninsula was accreting from 1955 to 1977.

Data collected over the last 25 years by the Washington State Department of Fisheries shows Long Beach to be accreting over that time period also (Figure 3). However, the rates of accretion are not constant over the entire beach (Appendix B). The rates are largest on the northernmost (21.4 ft/yr) and southernmost (17.1 ft/yr) portions, while the center curve (at 46° 31') shows a minimum accretion rate. The northernmost curve also shows the largest variations. Such variations are probably the result of bay mouth effects, as similar large variations occur on the southernmost section of the Grayland beaches.

Grayland

Mapping was available in the Grayland area for the years 1926, 1936, 1952, and 1977. These shorelines are portrayed in Figure 4 and the associated accretion-erosion rates in Appendix B. These data show a stable central section with

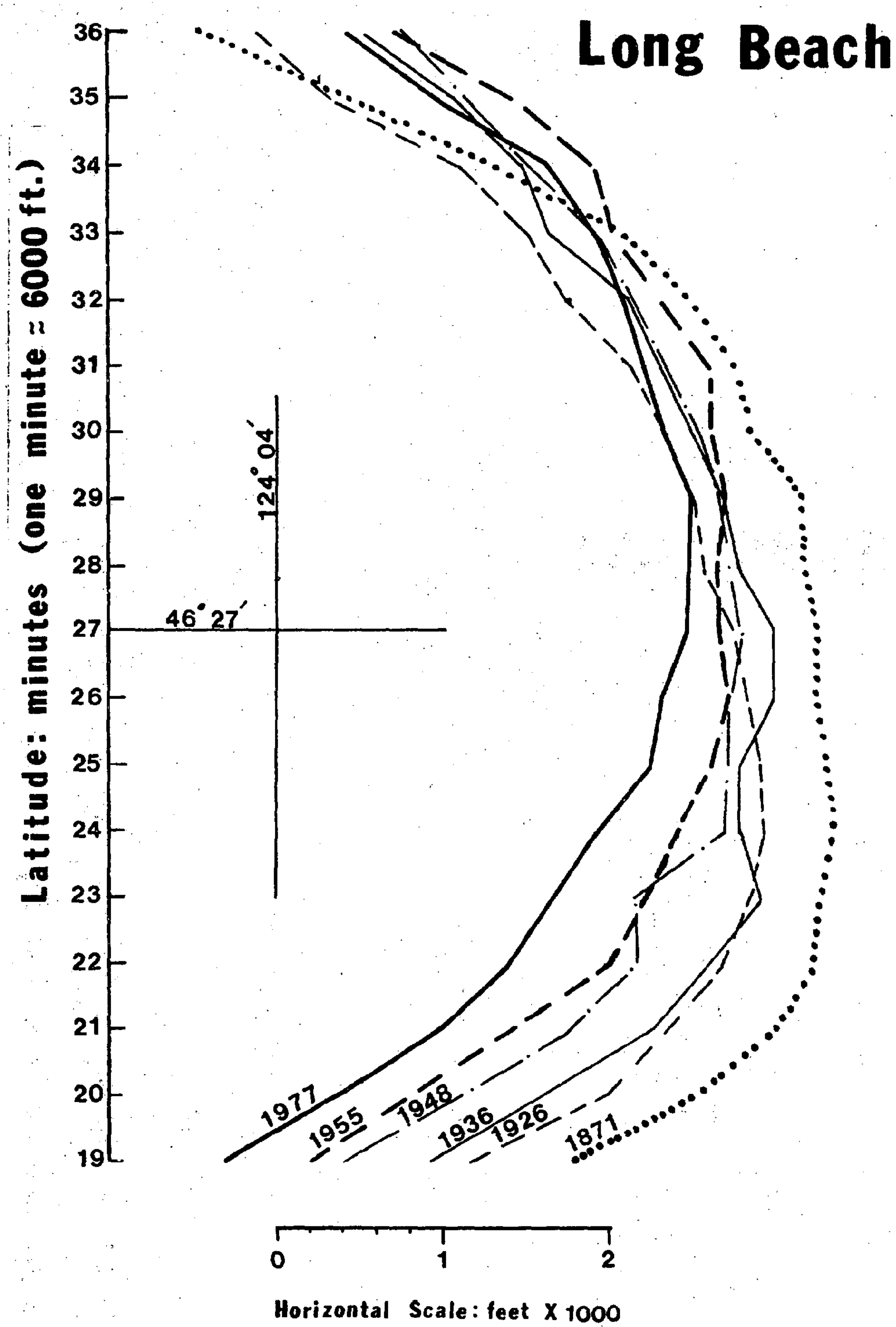


Figure 2. Historical Shoreline Changes
on the Long Beach Peninsula

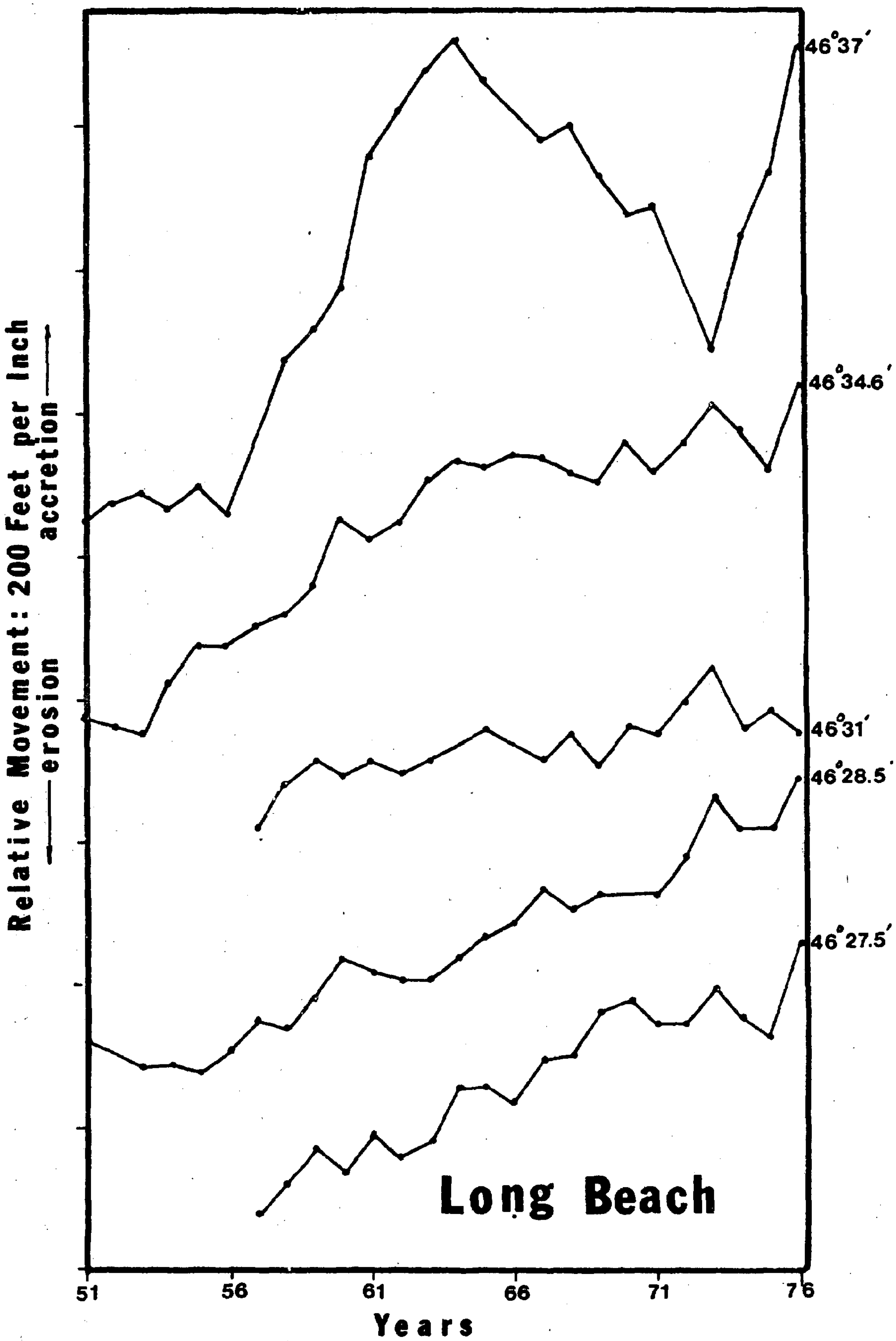


Figure 3. Changes in the relative locations of the +8.0 foot elevation.
Taken from Washington State Department of Fisheries data.

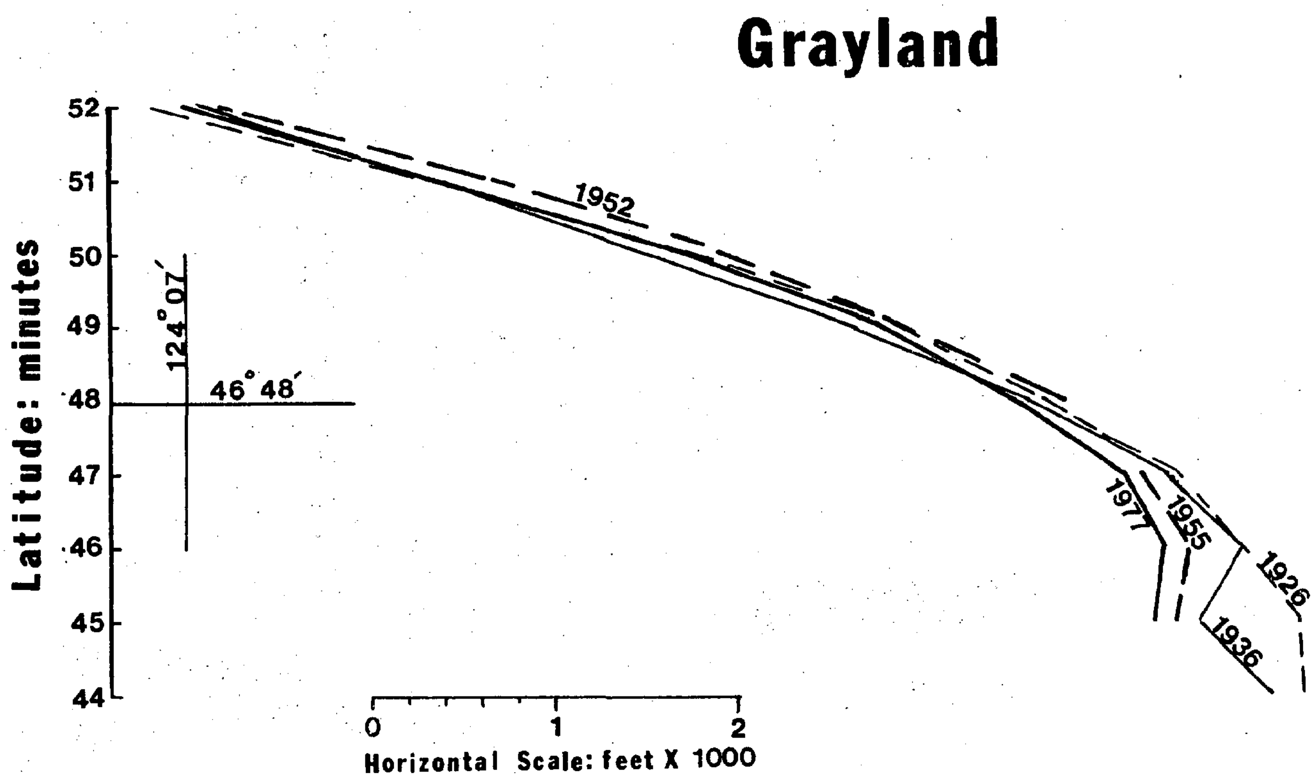


Figure 4. Historical Shoreline Changes
in the Grayland area

maximum changes occurring at the north and south ends of the beach.

The southern section is accretional in a westerly direction, and shows the largest amount of change in the entire Grayland area. Unfortunately, while the southern section of the beach is accreting towards the west, it is being eroded in a northerly direction as the mouth of Willapa Harbor migrates northward.

Curves of the Department of Fisheries data (Figure 5) show a general decrease in the accretion rates northward along the Grayland beaches. This northern portion of the beach, up to 46° 52', is reasonably stable in that it shows little change over the last 50 years.

North Beach

Mapping was available for the North Beach area from 1887, 1913, 1926, 1936, 1952, 1955, and 1977. These shorelines are portrayed on Figure 6 and the associated accretion-erosion rates in Appendix B. Here the pattern is similar to that of Long Beach with a great deal of accretion occurring next to the North Jetty. Indeed, the highest accretion rates encountered in the study were at 46° 58' where a 90-year rate of 47 feet per year occurs. The width of accreted sand diminishes rapidly northward to Copalis Rocks where it becomes zero.

North of Copalis Head the sea cliffs meet the high tide line and the beach is generally erosional. The erosional retreat of the cliffs is so slow that it was below the limits of precision for the older mapping. A comparison of the 1952 and 1977 air photos for the area just north of Copalis Rocks show a retreat of approximately 20 feet or about 0.8 feet per year. Near by, Copalis Head is actively slumping seaward, possibly as fast as the sea can remove the material.

Between Copalis Head and Iron Springs, the sea cliffs are overgrown with vegetation and do not appear to be actively eroding. North of Iron Springs to

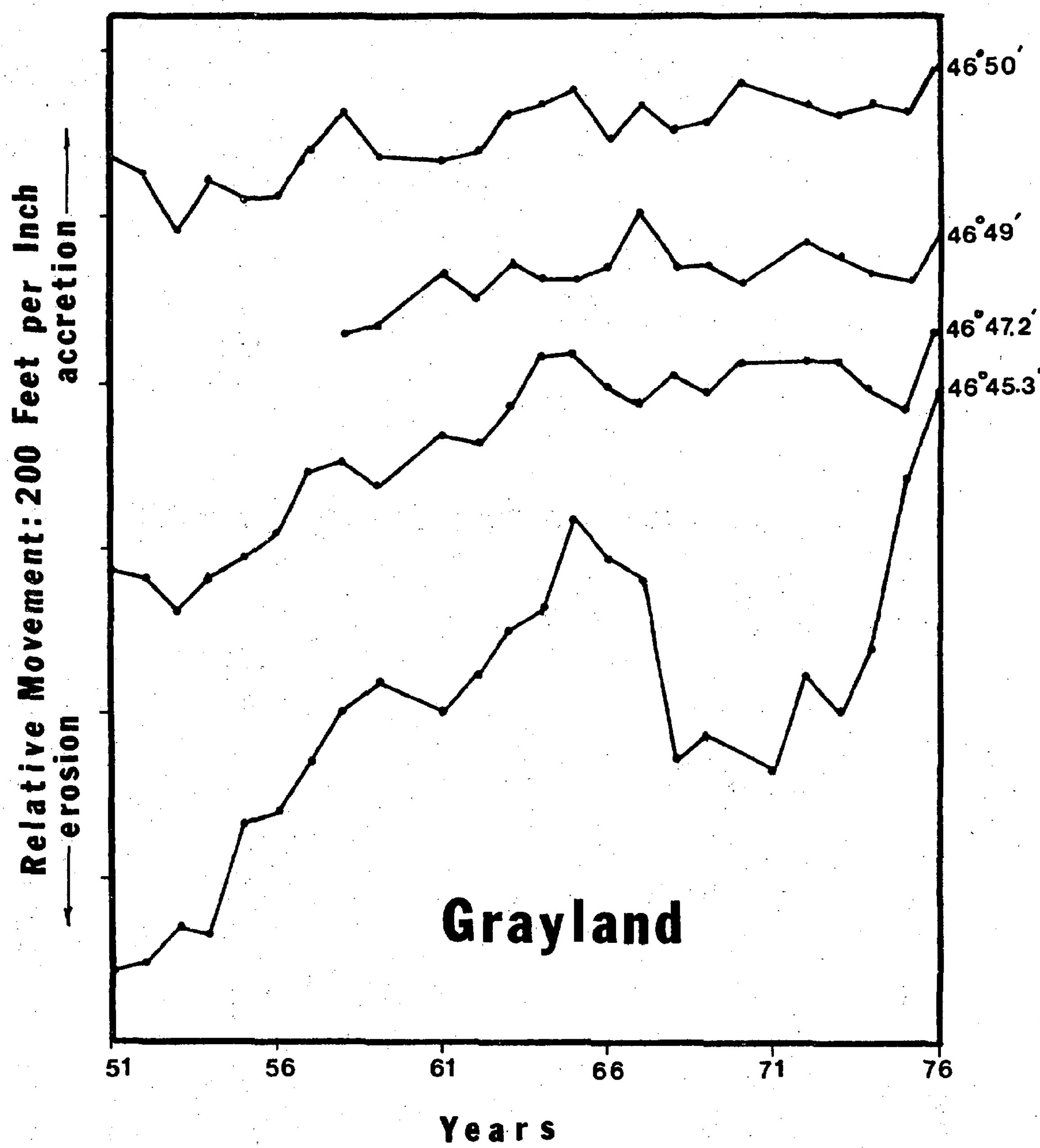
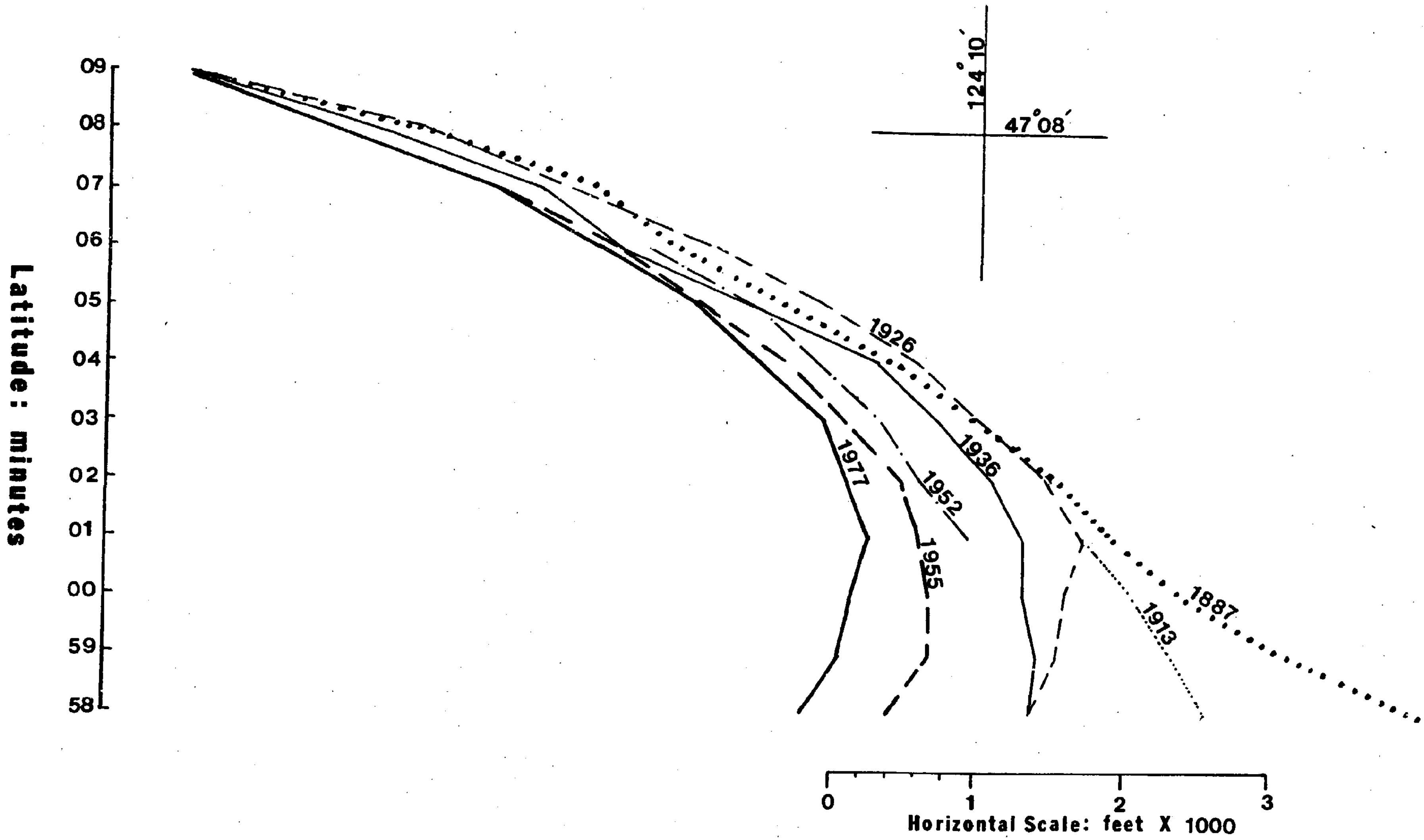


Figure 5. Changes in the relative locations of the +8.0 foot elevation. Taken from Washington State Department of Fisheries data.

North Beach



Latitude: minutes
09
08
07
06
05
04
03
02
01
00
59
58
124°10′
47°08′
1926
1936
1952
1977
1955
1887
1913
0
1
2
3
Horizontal Scale: feet X 1000

Figure 6. Historical Shoreline Changes
in the North Beach area

Pacific Beach, there is no vegetation on the sea cliffs and they are actively eroding, but not very fast. In this section there is a U.S. Coast and Geodetic Survey marker called "Bluff" that is no closer to the edge of the sea cliff now than it was in 1927 when it was implaced.

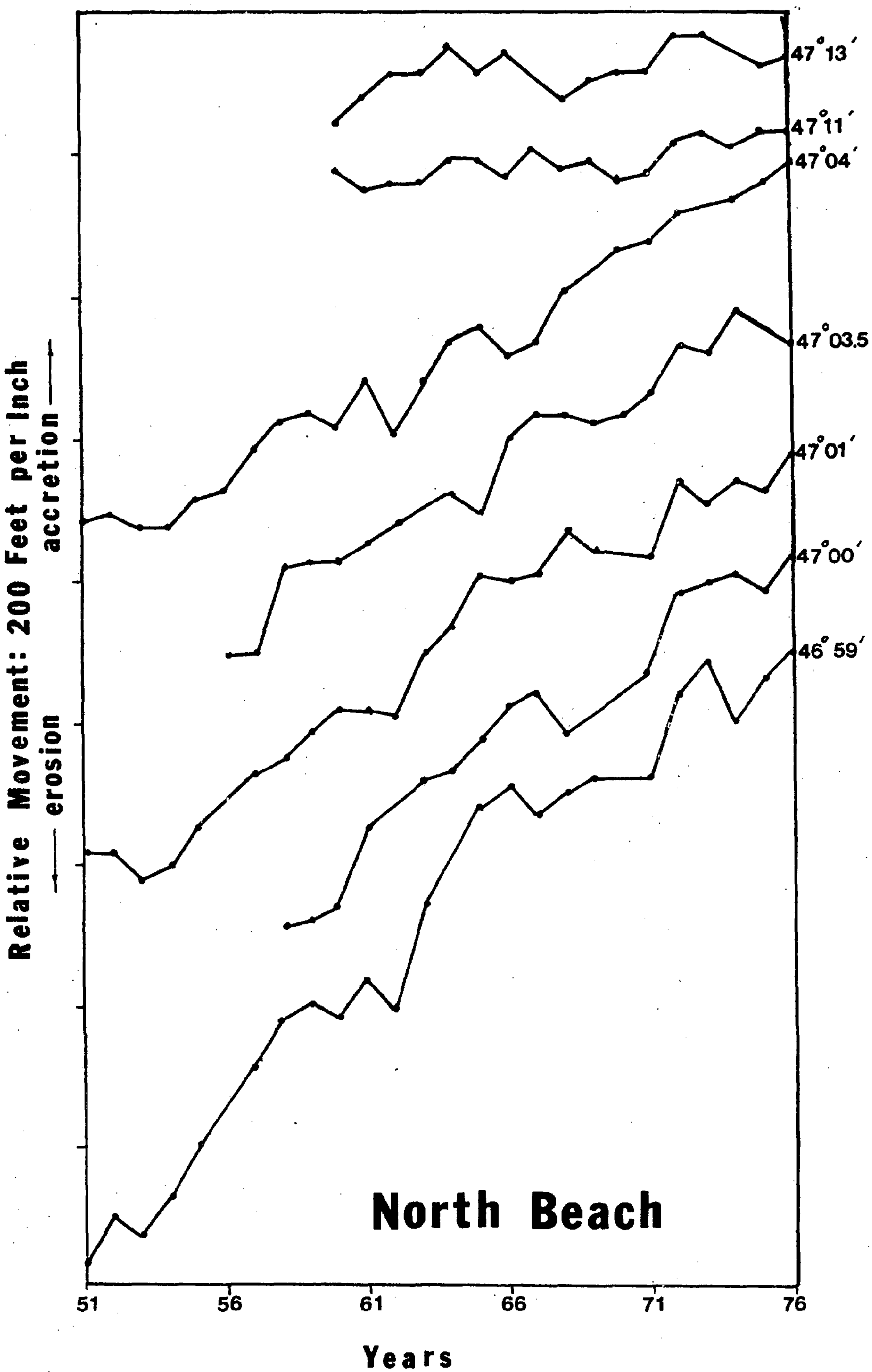
From Pacific Beach to Moclips, the Burlington Northern Railroad runs along the base of the sea cliff, 20 to 30 feet higher than the high tide level. The entire section is riprapped. A conversation with Harry Nordquist, the BN maintenance supervisor, revealed that the riprapping apparently stopped the erosion and that it required very little maintenance.

At the town of Moclips the sea cliffs retreat and a small pocket beach forms. Here the residents have built summer homes on the very edge of the erosion line, and are able to maintain the homes with pole bulkheads they emplace themselves. All these observations lead to the conclusion that, although the shoreline from Copalis Head to Moclips is geomorphologically erosional, it has not been eroding very fast, at least for the past 20 years.

The Fisheries data (Figure 7) confirm this general picture of high accretion rates on the southern portion of this beach, diminishing northward until the curves at Moclips are almost flat. Note the abrupt change in the character of the curves from 47° 04' to 47° 11'. These curves represent changes south and north of copalis Head which is the northern limit of active accretion.

The North Beach section is the only section in the study that has streams large enough to show the effects of the longshore drift. For example, the mouth of the Copalis River moved 2,700 feet northward in the 25-year period from 1952 to 1977. Even more spectacular is Conner Creek which lies to the south of the Copalis River. During the life of Conner Creek, its mouth has moved northward 2.4 miles. Further to the north, however, the mouths of the Moclips River and Joe Creek (at Pacific Beach) appear to be presently moving south. The streams

Figure 7. Changes in the relative locations of the +8.0 foot elevation. Taken from Washington State Department of Fisheries data.


47°13′
47°11′
47°04′
47°03.5′
47°01′
47°00′
46°59′
Relative Movement: 200 Feet per Inch
← erosion
accretion →
North Beach
51
56
61
66
71
76
Years

seem to be behaving in a cyclic fashion. Their mouths are pushed northward by the longshore drift, thus extending the channel length and reducing the gradient. This process continues until the stream system becomes so inefficient that the northerly prograding bar is cut off and the stream erodes a new mouth to the south and the cycle starts again.

Bay Mouth Changes

The major changes in the configuration of the shorelines have occurred at the mouths of Grays Harbor and Willapa Harbor; as well as adjacent to the Columbia River. In these areas the sand is not only moved by ocean waves, but also by tidal and river currents. Bay mouths are commonly characterized by rapidly shifting sands and this is true for the bay mouths along the Washington coast.

Grays Harbor

The earliest mapping in Grays Harbor (1852) shows a relatively narrow channel between Point Brown on the north and Point Chehalis on the south. Off the southernmost part of Point Brown laid Eld Island which was a prominent enough feature to be mapped in the Government Land Office Surveys in the 1850's. Successive maps show that between 1862 and 1891, Eld Island eroded away completely and Point Brown receded in a northeasterly direction about 4,300 feet (approximately 140 feet per year). During the same time period, Point Chehalis accreted about 4,300 feet in a northwesterly direction as shown in Figure 8.

By 1898 construction had commenced on the South Jetty. The 12,000-foot-long jetty was completed in 1902. This jetty provided an excellent barrier to the northernly longshore drift, and by 1904, the area behind the jetty had accreted 3,000 feet west. Between 1904 and 1933, the jetty subsided and eroded and the area behind it eroded back about 2,700 feet by 1939. A jetty rehabilitation project commenced in 1933, was completed in 1939, and by 1946, the area

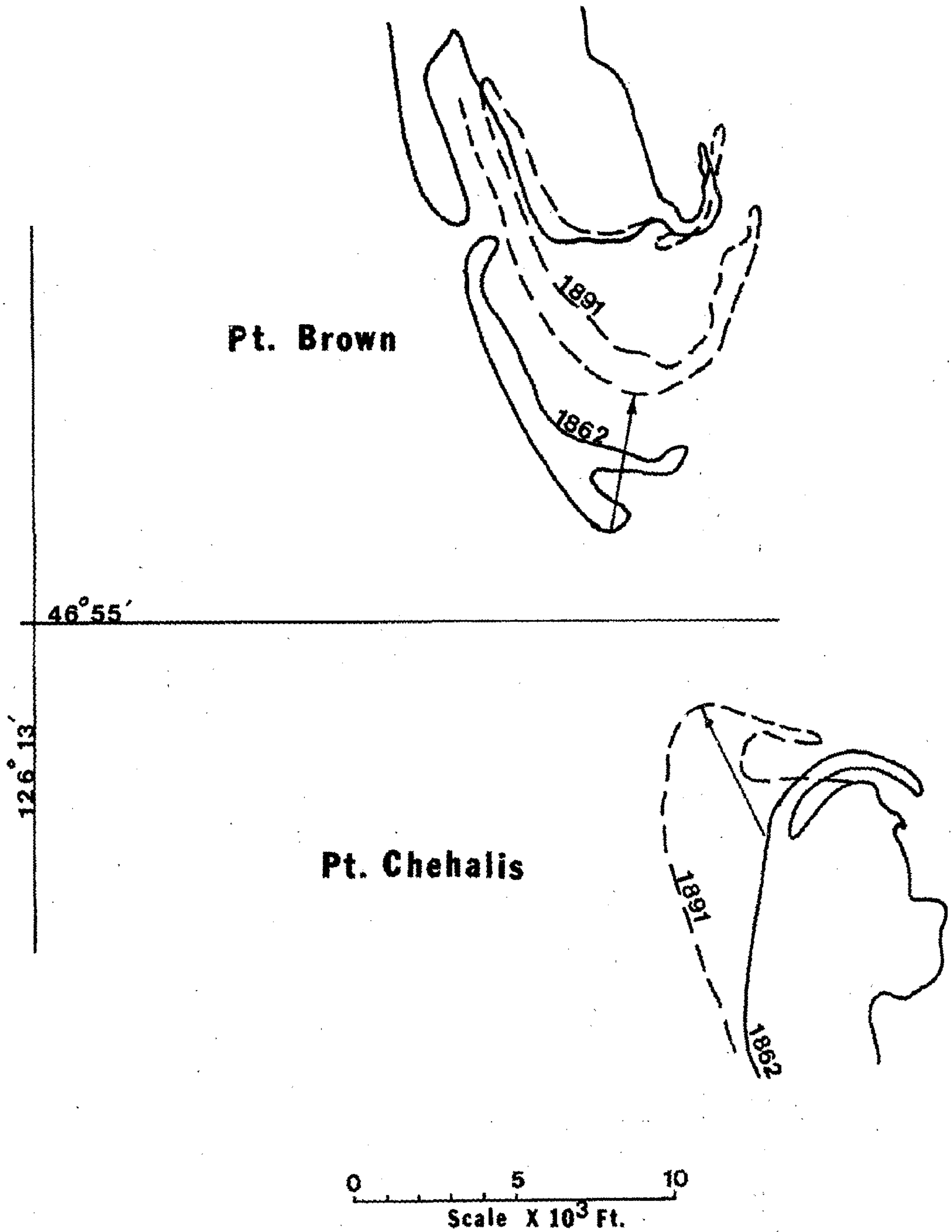


Figure 8. Bay Mouth Changes
adjacent to Grays Harbor

The arrows are both 4,300' long, indicating relatively similar rates of change on Pt. Brown and Pt. Chehalis.

south of it had accreted 1,100 feet from the 1939 position. Subsequent jetty erosion led to shoreline retreat after 1959 and the jetty rehabilitation in 1966 spurred another short period of accretion (Figure 9). Presently the area south of the South Jetty is in an erosional phase and it will probably remain so unless the jetty is again rehabilitated.

The construction of the North Jetty began in 1907 and the first 10,000 feet was completed by 1910. An additional 7,000 feet was added to the jetty between 1910 and 1913. By 1916 the jetty had to be reconstructed and raised. The jetty construction stopped the northward erosion of Point Brown, and prevented, to a degree, the southward accretion of it. So Point Brown accreted southwesterly along the north side of the jetty some 10,000 feet by 1930. Jetty reconstruction in 1942 was preceded by a slight erosional period, but ultimately resulted in another 3,000 feet of accretion to 1960. From 1960 to 1968, there was about 400 feet of erosion. It seems likely that jetty rehabilitation in 1975 will result in a few more years of accretion next to the jetty.

Comparison of the erosion-accretion rates next to the jetties of Grays Harbor leads to the following observations.

a) Whether the beaches are eroding or accreting is dependent to a large degree upon the state of repair of the jetty system.

b) The area behind the North Jetty has accreted faster and further west than the land behind the South Jetty.

c) The effect of the South Jetty only extends a couple of miles down (southward) the beach while the accretion next to the North Jetty is probably responsible for the beach configuration up (northward) to Copalis Rocks.

Willapa Harbor

In the later part of the 1800's the spits on both sides of Willapa Harbor

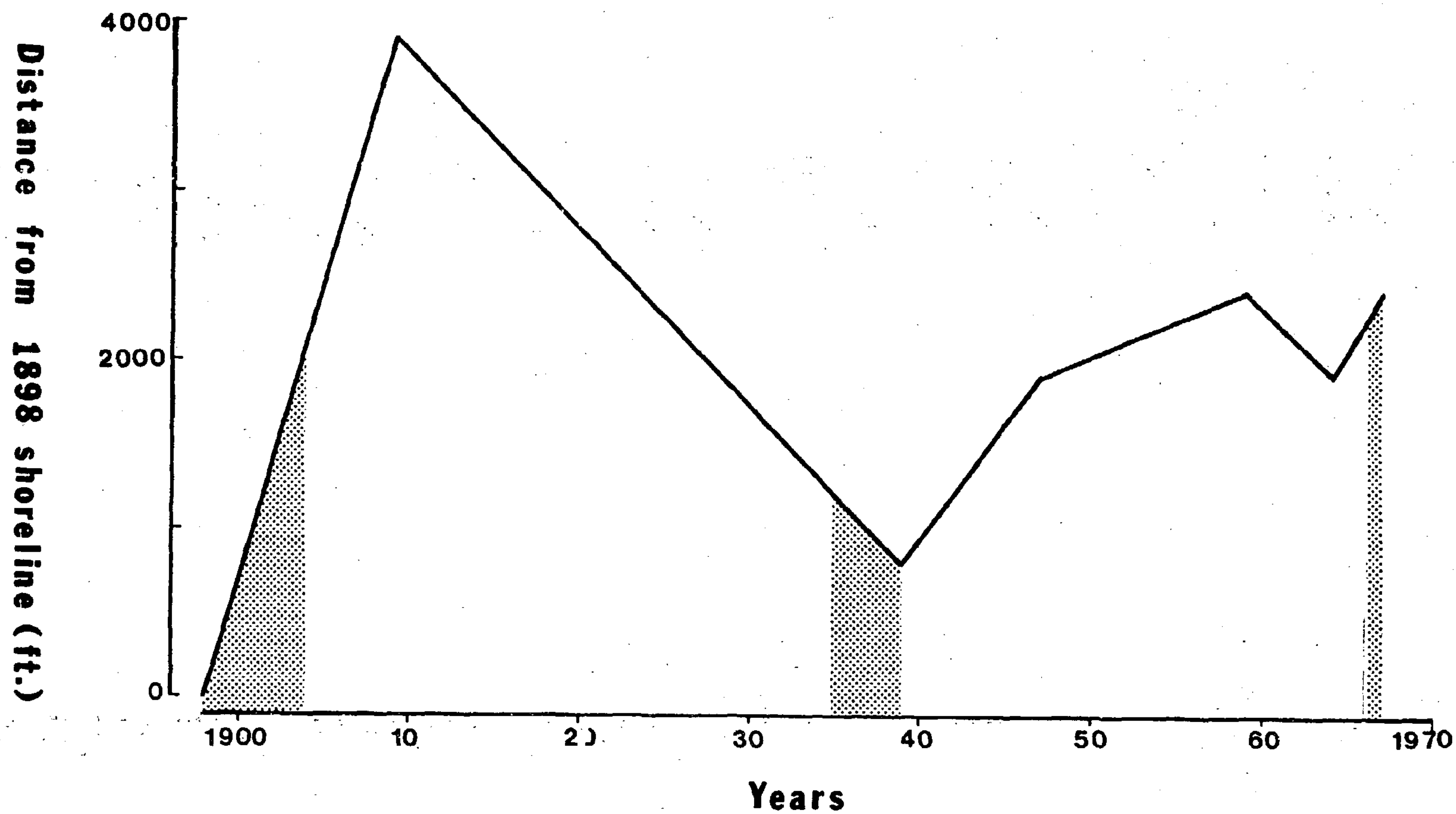


Figure 9. Erosion-accretion rates measured at a point 800 feet south of the South Jetty of Grays Harbor. The stippled pattern indicates periods of jetty construction or rehabilitation.

were migrating towards one another so that by the 1880's the bay month was only three miles wide.

Between 1852 and 1887, Cape Shoalwater migrated southward 2,500 feet (71 ft/yr), while Leadbetter Point migrated northward about 7,000 feet (200 ft/yr). Sometime between 1890 and 1911, this situation was reversed and both spits started to erode apart. The northward erosion at Cape Shoalwater has been continuous although at varying rates (Figure 10). But the erosion at Leadbetter Point has been interupted by periods of accretion so that, in total, its position has not changed a great deal since 1887 (Figure 11).

The U.S. Army Corps of Engineers describes the cyclic nature of the erosion rates as follows: "Periods of no erosion are attributed to the extended length of the outer bar and entrance channel southward resulting in reduced wave action on and temporary stabilization of the inner bar. The channel ultimately becomes too long to be efficient and breaks through the northern part of the outer bar, severing the bar, leaving the southern portion without a sand supply for nourishment. The severed portion of the outer bar is then driven onto the inner bar by ocean waves. The resultant enlarged inner bar crowds the north (main entrance) channel tight against Cape Shoalwater and narrows the channel. Resulting increased tidal velocities causes accelerated erosion of the shoreline. The restricted main channel also tends to force development of a secondary channel to the south near Leadbetter Point. Subsequent widening of the north channel due to erosion of the north bank and development of the south channel tends to relieve the pressure on the Cape Shoalwater shoreline, with erosion diminishing. The northern portion of the outer bar begins to build southward again and the cycle is repeated. This cycle appears to take from 13 to 20 years, normally."

It is likely that the erosion at Cape Shoalwater will continue its cyclic northward path, until the channel entrance moves back to the area near Leadbetter Point and the northward migration process starts over again. There is some weak evidence that this may have happened in the past prior to 1890. The evidence is the intersecting dune ridges on the Leadbetter Spit that show periods of erosion on the spit. There are no data in this report predicting when such an event might occur and considering that the channel has been moving northward since 1890, it seems reasonable to assume that it will continue northward at least for the time period covered in this report.

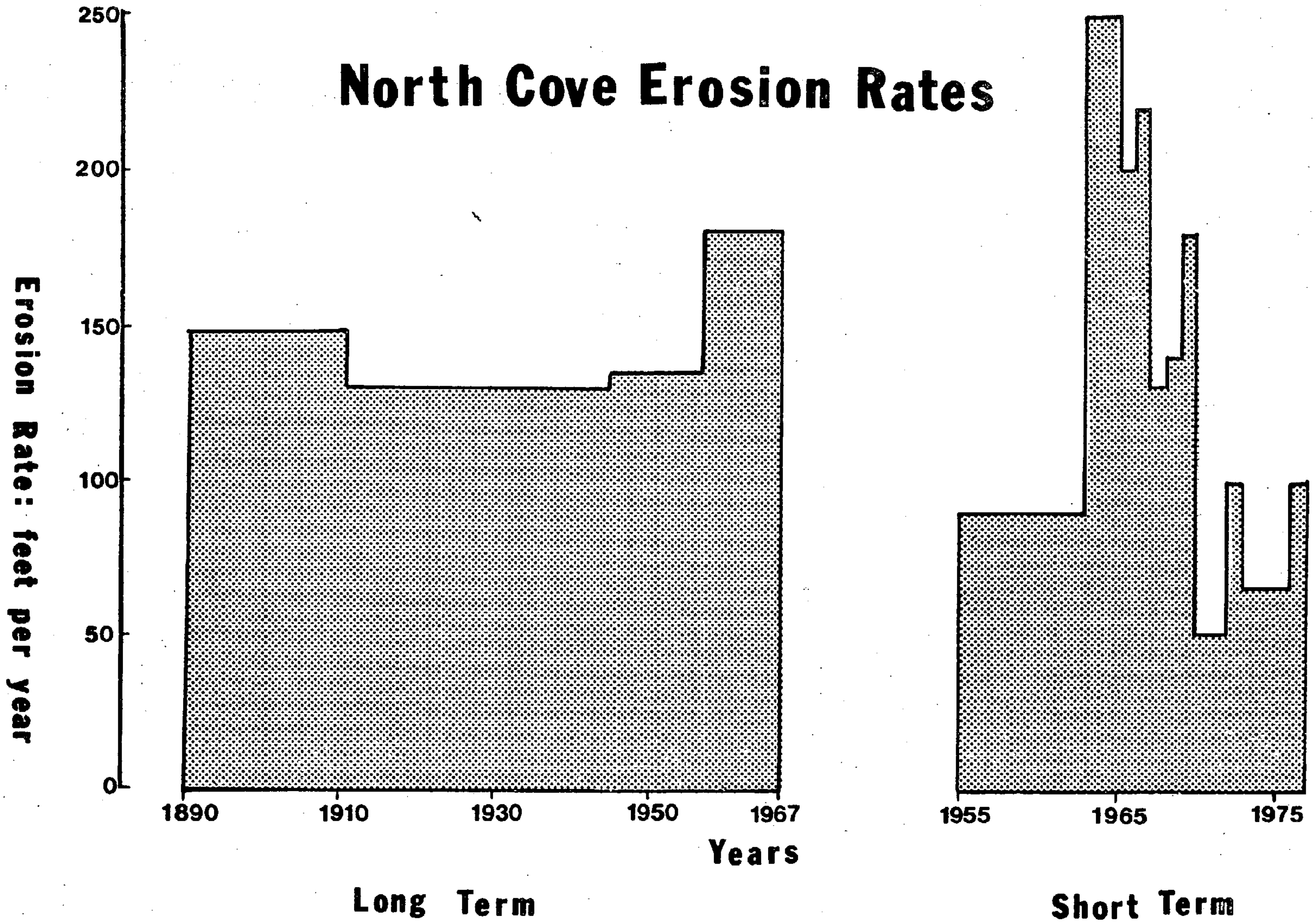


Figure 10. North Cove erosion rates. Long-term data was taken from U.S. Army Corps of Engineers Reports (1969) and the short-term data from the Pacific County Assessors Office.

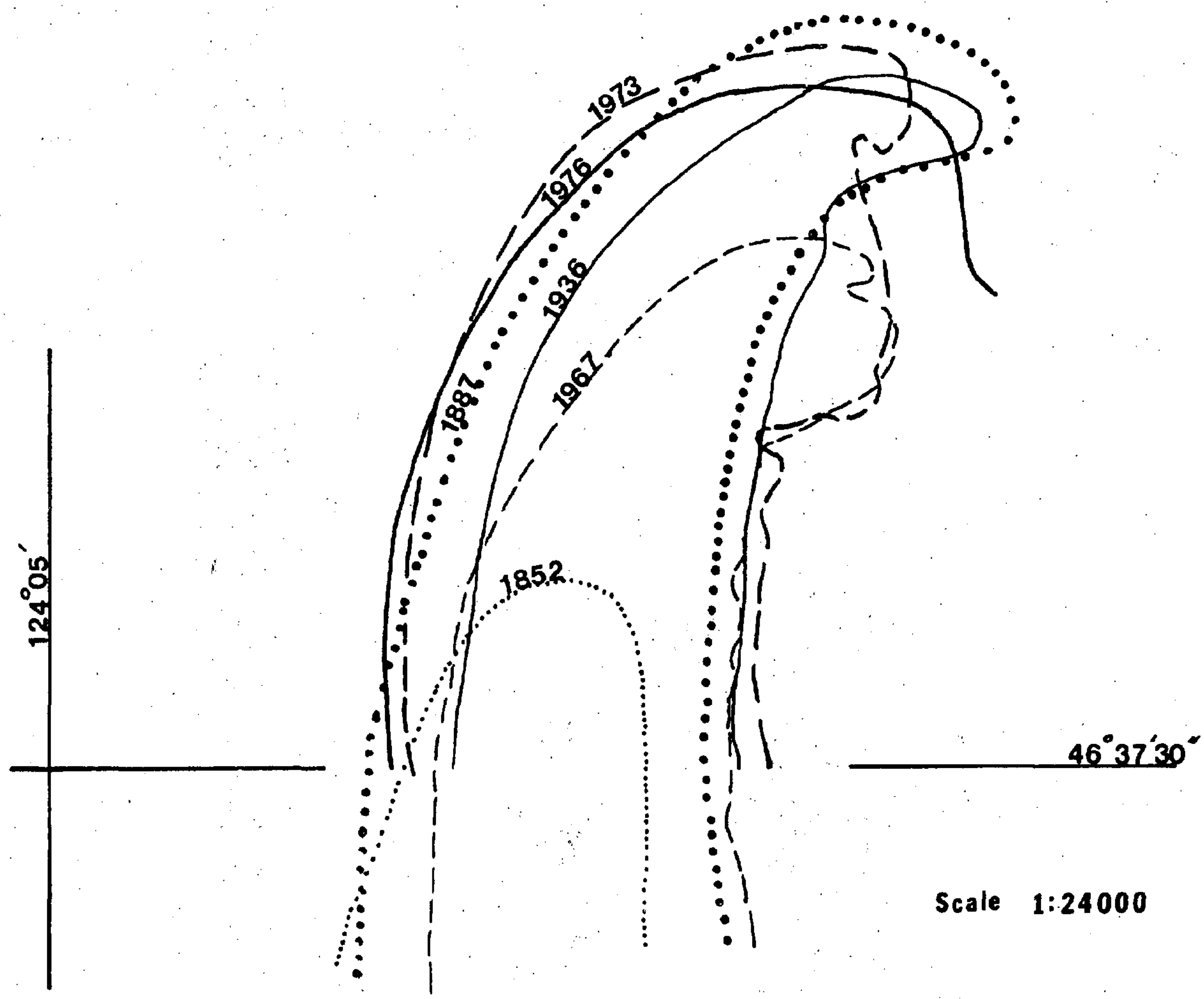


Figure 11. Historical Shoreline Changes on Leadbetter Point

A PRELIMINARY SAND BUDGET

The factors involved in a sand budget are shown in Figure 12. Many of these factors are poorly known. In some cases there are differences of opinion as to the direction of movement of the sand which must be resolved before the rates of sand movement and the volumes moved can be considered seriously. It is the purpose of this section to summarize the "state of the art" as described in the literature concerning the factors in the sand budget.

Sources of the Sand

Heavy mineral studies done by Ballard in 1964, and confirmed by others (Lockett, 1965; Scheidegger and others, 1971) show that the beaches of Southwestern Washington are composed of sand of Columbia River origin. It is possible that sea cliff erosion from the area north of Copalis Head, and some of the rivers of the Olympic Peninsula contribute sand to the system, but this contribution has never been identified by sediment analyses.

The sand is carried as bed load in the Columbia River system although bed load volumes have not been measured directly. They are usually attained by measuring the suspended load volumes and assuming the bed load to be a percent of the suspended load. Sternberg, et al (1977) list the following estimates of suspended load

Investigator	Year	River Position	Annual Suspended Load (tons/year)
Van Winkle (1914)	1910-11	Bonneville	7.0×10^6
Judson & Ritter (1964)	1950-52	Denudation Rate Calculation	3.3×10^7
Haushild, et al (1966)	1962-63	Vancouver	8.4×10^6

Whetten (1969) who also reported some of the above figures estimated that the bed load was 10% of the suspended load estimated the Columbia River bed load at

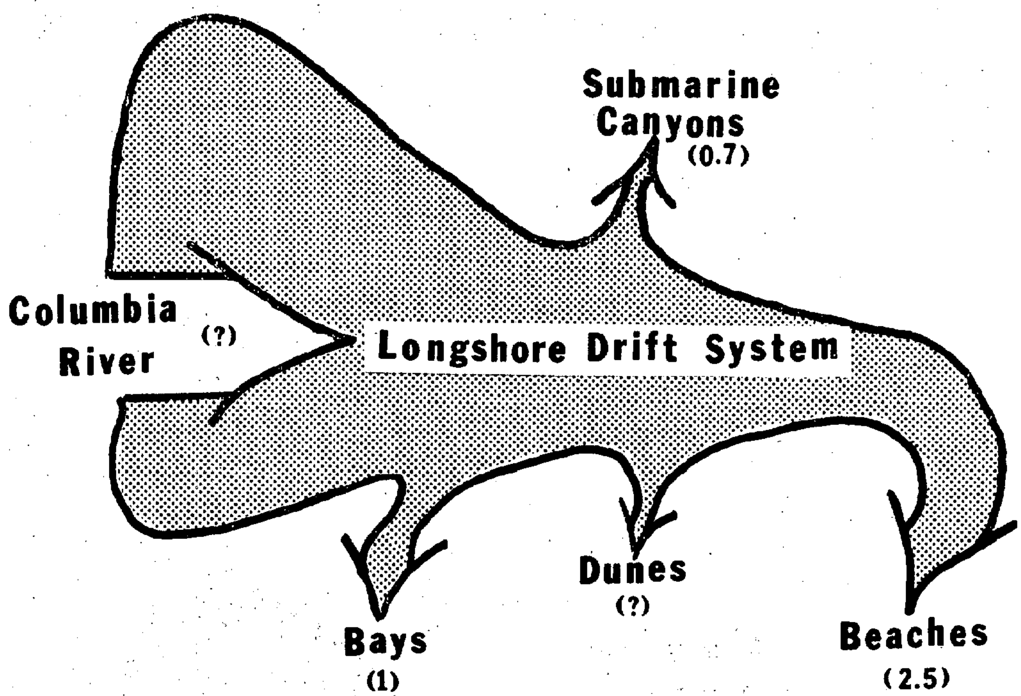


Figure 12. A preliminary sand budget for the longshore drift system. The figures in parentheses are very rough estimates of annual volumes in millions of cubic yards.

somewhat less than 10^6 tons/year. This number was based on his study of sand wave movement in the Bonneville resevoir. Gross (1972) figures ten million tons as the total sediment descharge of the Columbia River. By reworking long-term scour and fill data published by Lockett (1962), he concludes that about 45% of the sediment discharge is deposited within 10 kilometers (6 miles) of the river mouth and 35% is deposited within the entrance channel annually.

Jay & Good (1977) report unpublished U.S. Geological Survey data on sediment transport in the Columbia River. According to U.S. Geodetic Survey estimates the proportion of sand, as a percentage of the total sediment transport at Vancouver, varies from 0% for flows of 100,000 cfs to 65% for flows of 700,000 cfs. The U.S. Geological Survey approximates the coarse sediment transported by the Columbia and Willamette Rivers as 2.41 million tons during the water year 1963. It should be noted that the sediment load of the Columbia River is extremely variable, ranging from 5.8 to 41 million tons for the years 1968 to 1970. Another example of the variability of sediment transport is that in 1965, a single storm contributed 8.6 million tons of sediment during one week. Jay and Good (1977), using U.S. Geological Survey data, estimate the bed load transport at Vancouver as ranging from 1 to 10 million tons annually from 1963 to 1970.

Longshore Drift

The direction of longshore drift displays a seasonality which is northward in the winter and southward in the summer (Ballard, 1964). Thus the beaches display accretion patterns characteristic of drift in both directions. Because of the greater intensity of the winter storms, the rate of drift is greater in the winter than it is in the summer. This results in a net northward drift along the Washington coast.

This general scheme of longshore movement of sand is altered somewhat by local wave refractions, as is the case next to the North Jetty of Grays Harbor (Dave Schuldt, personal communication, 1978). Thus there are, indeed, local alterations to the general trend of sand movement.

It is important to note that, although there is a net northerly drift, the winter storms that are moving the sand in this direction are also removing the sand from the beaches. Conversely, the summer southward component moves the sand onto the beaches. So accretion adjacent to structures and headlands that block this summer sand movement appears to be faster than in other areas. The volumes of sand involved in the drift have been calculated by the U.S. Army Corps of Engineers (1973). These calculations were done by several methods but were all hindered by a lack of wave data. The averages of the methods used are 4.7×10^6 cubic yards/year northward and 2.5×10^6 cubic yards/year southward in the area of North Beach. The same investigations (U.S. Army Corps of Engineers, 1973) also point out the accumulation rates of sand behind the North Jetty of Grays Harbor at 2.3×10^6 cubic yards/year form 1910 to 1928 and 1.7×10^6 cubic yards/year from 1942 to 1959.

Bay Entrapment

The estuaries involved in this study are drowned river valleys. Such estuaries appear to be sediment traps removing sand from the longshore drift by the bottom-in flow of seawater associated with the salt wedge (Rusnak, 1967; Meade, 1969). Heavy mineral analyses led Scheidegger & Phipps (1976) to conclude that "Grays Harbor receives marine sands of Columbia River origin."

The U.S. Army Corps of Engineers (1973, p. A-33) calculated from dredging data that as a result of jetty deterioration at that time, about 610,000 cubic yards/year of the dredging in Grays Harbor results from the littoral drift entering the estuary from North Beach. This volume of sediment comes from a very small portion of the estuary, the channel, and there are no calculations of how much marine sand is deposited in the estuary outside of the channel. It would seem reasonable to consider that at least as much is deposited at non-channel sites, making a total of about a million cubic yards of sediment entering the estuary annually. However, with the subsequent jetty repair the amount of sand entering the estuary would be decreased. After considering the volumes of sediment involved, we estimate that the net annual loss to the longshore drift system is roughly half a million cubic yards into Grays Harbor.

The conditions at Willapa Harbor suggest that it can entrap more sand than Grays Harbor because it lacks the jetties. A possible offsetting factor is the erosion at Cape Shoalwater. Some of this sand may enter the littoral system. Considering these factors, it appears that Willapa Harbor can be assigned to entrap about half a million cubic yards of sand annually.

Transport Down Submarine Canyons

The removal of sediment from the near shore system by channeling it down the submarine canyons is well documented. Studies from Oregon State University show sand with a Columbia River mineralogy in the submarine canyons along the Oregon-Washington coast. Using one of these studies (Nelson, 1966), it is estimated that approximately one-third million yards of sand per year has been going out on the Astoria Fan, via the Astoria Canyon (averaged over the past 6,600 years). The other canyons, like Willapa, Grays, and Quinault Canyons, probably act in a similar fashion, but do not necessarily carry similar volumes.

Cross-shelf Transport

Nittrouer (1978) describes the sediment on the Washington continental shelf as: relict on the outer shelf; bounded by a mid-shelf silt deposit; bounded by near shore sands. This band-like pattern parallel to the shore precludes cross-shelf transport of sand from the near shore except through submarine canyons as mentioned above.

Loss to the Dune System

The dune system along the Washington beaches is progradational, with a series of long dunes formed parallel to the coast line. The positions of the dunes are stable; they do not generally migrate. In most areas the recent losses to the dune system would be manifest as vertical growth in the primary dune. Interviews with beach residents suggest that this is occurring along many areas of the beaches but the data was not quantifiable.

Beach Accretion

The data presented in this report allows only a crude approximation of beach accretion volumes. A much better estimate could be obtained from studies of nearshore and beach profiles, if they were available. Approximately 2½ million cubic yards annually were added to the beaches between 1952 and 1977. This figure involves the following assumptions:

1) The accretion extended uniformly out to a depth of -10 feet (arbitrarily chosen) and back to the base of the dunes at +10 feet elevation.
2) From the Copalis River south to North Head, the beach was accreting although at different rates. There was no significant contribution of sand to the system from beach or cliff erosion.

Sea Level Changes

Long-term sea level changes for the West Coast have been determined by

Hicks (1972). His data, taken from tidal information, suggest a 10 cm rise (averaged over the West Coast) for a period from 1890 to 1970. If it is further assumed that the average beach slope is about one degree, then such a sea level rise would account for about 19 feet of erosion for that time period.

The two closest stations to the area of interest were not used by Hicks (1972) because of "river discharge variations" (Astoria), or "acute emergence from recent glacial melting" (Neah Bay). However, one can calculate the shoreline change based on Hicks' apparent secular trends (1940-1970) for each of these stations. Assuming a one-degree land slope, the trend from the Astoria station would produce an accretion rate of 5 cm/yr while the trend from Neah Bay yields a 7 cm/yr accretion rate.

Even though the local stations show accretion and the regional West Coast data suggests erosion, it is clear that the beach changes caused by secular sea level changes are at least two orders of magnitude smaller than the other measurements in this study.

Discussion

The factors involved in the preliminary sand budget are not well known and the volumes of sediment quoted in this section must be considered approximations. For all the inaccuracies, however, a budget approach allows one to consider the total system a lettle moré rigorously than would be otherwise allowed.

Simplistically, the littoral system appears closed with Columbia River sand imput and outputs by beach accretion, bay entrapment, dune growth, and transport down submarine canyons. When one of these factors is affected by man or nature, the others will respond to balance the budget.

The construction of the jetties at Grays Harbor and the Columbia River, altered the system by considerably increasing the accretion rates behind them and by forcing sediment from the Columbia River offshore into deeper water, where its return to the longshore drift system was less efficient. At roughly the same time the natural spits bounding Willapa Harbor started to erode apart.

Thus the trapping of sand by the jetties removed large quantities of sediment from the longshore drift system. In the meantime, the areas behind the jetties appear to be nearly filled. Hence, if the jetties are maintained in their present conditions, there should be relatively more sand available for beach nourishment in the future.

Historically, dams act as sediment traps, and there has been concern that the impoundment of the Columbia River might reduce the sediment volume in the longshore drift system. Apparently such has not been the case, to date, with the Columbia River system.

Most of the sand is transported during high flow times, and as the dams control the high river flow periods, the rate of sand transport will diminish. Furthermore, Lockett (1962) and Jay & Good (1977) both express concern that dams on the Columbia River and its tributaries have greatly reduced the spring freshets which flush sediment from the estuary. The amount of sediment transferred from the estuary to the longshore drift system is one of the weakest portions of the budget considerations. None the less, observations from his study do not indicate diminished beach accretion rates attributable to the dams.

Dredging on the Columbia River and in Grays Harbor involves large volumes of sediment. About the same order of magnitude as is involved with any factors in the sediment budget. Disposal of these dredged materials may well become an important factor in future beach budget considerations.

YEAR 2000 PROJECTION

Introduction

It is possible to graphically extrapolate historical data to project future shoreline conditions. The accuracy of the projection is dependent upon the continuity of the individual processes that make up the total beach system. That is, if the beach behaves for the next 22 years the way it behaved for the last 25 years, then the projection will be accurate. Unfortunately, variables in the recent past are only scarcely identified and poorly quantified. For instance, the driving force of sediment movement along the coast is the weather. It's the rain that erodes the land and brings sand to the seashore, and it is the wind that generates the waves (and some of the currents) that move sediment along the shoreline. Who would make a projection for the next 22 years of weather conditions?

Nevertheless, for all the inaccuracies, a projection of future conditions is useful because it is fundamental to managing the shoreline in that it facilitates land use planning. Also, a projection is really a hypothesis that is tested each year. Thus, shorter-term changes can be observed and considered relative to the over-all scheme rather than considering such short-term changes as incoherent, random events.

Procedure

The year 2000 shoreline was projected using the following procedures:

1) The changes between the 1950's and 1977 are the most recent and thus the best data to use. Erosion-accretion rates from this time frame will be the fundamental data for the projection.
2) The primary rates used come from measurements from aerial photography.

These measurements are modified in the area of the Fisheries profiles as the latter are considered to be at least an order of magnitude more precise.

3) The Fisheries profiles accretion rates were obtained by regression analyses on all the data that were available for any given profile.

Assumptions

The following assumptions are inherent in the projection:

1) The climatic conditions for the next 22 years will be about the same as for the last 25 years.
2) The source of sand available to the beaches will be the same, as will be the quantities.
3) The present jetty systems will remain the same, or at least be maintained at about their present conditions.
4) The bay mouth changes at Willapa Harbor will continue without a drastic change (to the south) of the channel.

Discussion

The year 2000 map consists of several sheets, each representative of a U.S. Geological Survey Quadrangle Map (Appendix C). The maps are designed so that the future shoreline can be scaled off and transferred to the appropriate quad sheet. Scaling should be done east-west from the line of longitude on the year 2000 map. The vertical scale of the sheets is one inch equals one minute of latitude (6,000 feet), while the horizontal scale is one inch equals 1,000 feet. In the erosion areas where the change is too small to show up on this scale, a stippled pattern is used. Areas where the shoreline is questionable or where data maybe inadequate are dashed.

The changes at the tip of Leadbetter Point are not included in the maps on Appendix C, but the reader is referred to Figure 11. On that figure, the year 2000 shoreline will presumable lie somewhere between the 1887 shoreline and the 1967 shoreline. The problem on Leadbetter Point is that the apparent long-term erosional trend reversed itself between 1967 and 1973, and from 1973 to 1976 it started eroding again. The latter is far too short a time span upon which to base a projection.

Changes in the Cape Shoalwater area were taken from U.S. Army Corps of Engineers (1969) projections. The projected shoreline is dated 1994 rather than the year 2000 and appears on a copy of a portion of the North Cove Quadrangle in Appendix C.

SAND DUNES AND MANAGEMENT ISSUES

The sand dunes of coastal Washington occur as parallel dune ridges. The ridges are formed by vegetation catching and holding wind-born sand. As the shoreline has prograded, new ridges are formed in front of the older ones, leaving a shallow depression between and leaving the older dune ridge without a source of sand. Across the Long Beach Peninsula, there are approximately 20 mappable dune ridges.

The height of the ridge is probably a function of its active life span (the longer it's active, the higher it gets) and especially the efficiency of the vegetation to trap the sand. The present western-most ridge called the primary dune (or foredune) is relatively high which may be a result of stabilization through the introduction of European beach grass Ammophila arenaria (L.) Link.

According to Cooper in a personal communication to Wiedeman in 1965, the height of the present primary dune has developed since the establishment of the European beach grass. This grass was introduced to Washington and Oregon in the late 1800's from Europe (Wiedeman, 1966). It has been used in Europe for centuries for sand dune control and attains maximum growth and vigor where sand deposition by wind is greatest, i.e., in the upper reach of the backshore. The grass has a strong stabilizing effect on sand and effectively reduces the amount of sand moving inland off the beach. It grows closely associated and interspersed with American dunegrass (Elymus mollis Trin.) and in many locations it has nearly replaced this native species because of its more aggressive growth.

Other plants that become established in the foredune as pioneers in the ecological succession are the silver beach weed (Ambrosia chamissonis Less.), yellow abronia (Abronia latifolice Esch.), American sea rocket (Cakile edentula Bigel.), seashore lupine (Lupinus littoralis), and seashore bluegrass (Poa macrantha).

The European beach grass and the silver beach weed are the dominant pioneer plants observed in the ecological succession pattern of Washington beaches in this study. These and other pioneer plants mentioned are vigorously controlled by the shifting surface of the sand due to wind and wave action. As the plants increase in number and size, the sand becomes stabilized and there are related changes in plant associations (Kumler, 1966).

However, drifting sand and/or wave action can cause either advances or retreats in the succession of dune plans. Similarily man-caused removal of sand in the foredune area can lead to a retreat of the dune vegetation. Alteration or sand removal from a stabilized primary dune also may be the reason for considerable change in the number and location of pioneer plants of the foredune and their role in the dune stabilization.

Tolerance of Dunes to Activities of Man

Ian McHarg (1969) reports on guidelines developed in Holland through years of experience in his book, Design With Nature (chapter, "Sea and Survival"). Battelle Northwest adapted McHarg's work in their report, "The Future of the Long Beach Peninsula" (1970) to list the general tolerance characteristics across the Long Beach Peninsula. The Battelle study points out that the primary dune is a "defensive line protecting lands behind it from storm waves and high tides and should be considered intolerant to unnatural disturbances." They go on to say that the beaches, the trough, and the back dune are considerably more tolerant to the activities of man.

This concern for the primary dune is addressed in the National Flood Insurance Program, Section 1910.3 (e). This section of the program suggests that the primary and secondary dunes are not only keys to the survival of the beach and coastal areas, but that they are important as protection against loss of life and property during flooding. Because of such concerns, a new provision was added to the revised rule requiring communities to prohibit man-made alteration of sand dunes.

Measured Sand Dune Changes

In the Long Beach area the Pacific County Engineering Office set 55 steel pole markers along the seaward edge of the foredune in September and October 1976 as part of a Department of Ecology grant to establish a base line from which certain dune characteristics and changes could be measured. The markers were set in concrete which was flush with the surface of the sand in the foredune a few feet west of the most dense vegetation. It is assumed that a general relationship exists between the accumulation of sand above the base of the marker posts and the amount of sand available to build the foredune along a particular beach sector. By visiting 36 of those markers and digging down to the concrete and then measuring the dipth of the sand removed, it was possible to measure vertical increase in sand in the primary foredune.

The average increase in depth in approximately 20 months was 20.3 inches, with a range of zero to 33 inches (Figure 13). The areas that had minimal growth appear to be associated with access roads to the beach. Minimal vertical dune growth is indicated in Figure 13 at four locations: near 14th Street in Long Beach, in the vicinity of Cranberry Road, approximately one mile south of Klipsan Road, and near Bay Avenue in Ocean Park. At the 14th Street location and the south Klipsan location, there is no maintained access road. However, heavily-used, four-wheel drive roads are located in both of these areas. These gaps in the dune permit sand to move through the foredune and be blown out of the backshore area.

By using the Pacific County beach markers mentioned above, it is possible to make an estimate of foredune advance or retreat since October 1976. There

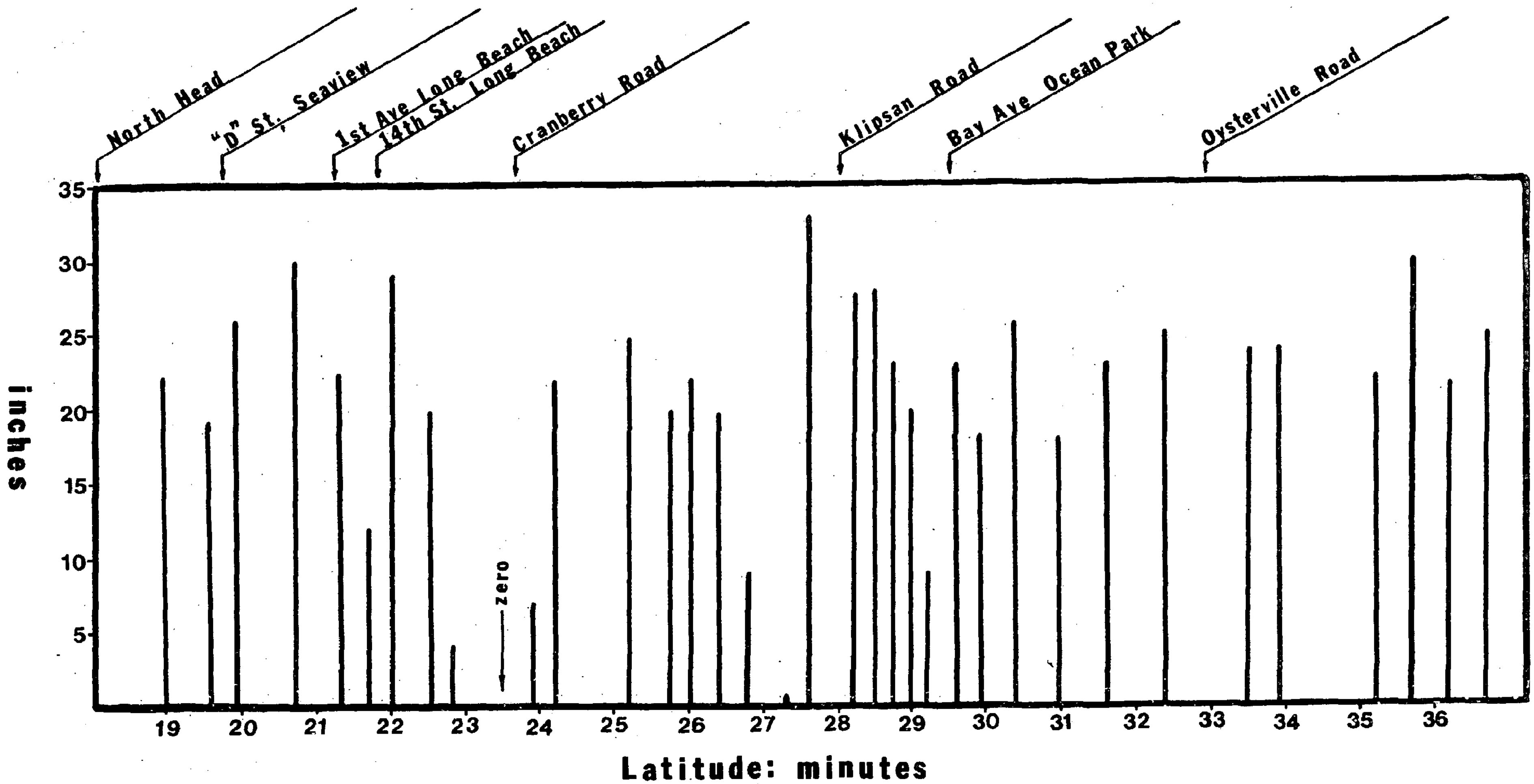


Figure 13. Changes in the depth of accumulated sand on the vegetation markers on the Long Beach Peninsula. Note that the areas of least amount of land accumulation are generally associated with an access road.

was only one area of foredune accretion, that being the post located 0.36 mile south of D Street in Seaview, where an estimated 20 feet of growth has occurred.

The only other area of noticeable change was the retreat of the foredune in the vicinity of marker posts located north and south of Cranberry Road. The southern end of this retreating foredune is 0.20 mile south of Cranberry Road and the northern end is 2.07 miles north of Cranberry Road. Five marker posts in this retreating foredune area averaged a loss of 46 feet, as indicated by the retreat of vegetation in an easterly direction.

Although the receding dune area is only based on the subjective judgement of relation of vegetation to the marker posts, it does reinforce the more quantitative indicator of lack of vertical dune growth in the Cranberry Road area.

Maximum vertical dune growth on the Long Beach Peninsula since the marker posts were established in September 1976 was 33 inches. This post was located 0.46 mile south of Klipsan Road, and is 0.42 mile north of a marker post that measured only one inch of vertical growth. These two marker posts, only 0.42 miles apart, present the greatest variability in the set of 36 posts measured. Table 2 shows the vertical dune growth at various posts in the vicinity of Klipsan Road.

Table 2: Vertical dune growth in the vicinity of Klipsan Road since September 1976.

Station Number	Miles from Klipsan Road	Direction	Vertical Dune Growth in Inches
020	2.26	South	22
021	1.85	South	20
022	1.43	South	9
023	0.88	South	1
024	0.46	South	33
025	0.27	North	28
026	0.55	North	28
027	0.87	North	23

In observing the sand dune around Stations 022 and 023, several man-caused features may explain the lack of vertical growth. At Station 022 the dune buggy road through the dune approximately 900 feet to the north may be a factor. The continual driving of dune buggies and four-wheel drive vehicles in the foredune and primary dune in this area may contribute to the problem. Station 023 has a dune buggy road through the dune approximately 1,100 feet south of the marker post. There are 12 dune buggy roads through the dune between Cranberry Road and Klipsan Road. Also, 200 feet south of Station 023, it appears that the primary dune was cut down to open the view for a residence. This type of alteration probably contributed to the lack of vertical growth at Station 023.

Recent Dune Stabilization Attempts

A dune stabilization project has been started at Twin Harbors State Park. The installation of "snow" fences of top of a secondary dune in March 1978 has accumulated approximately 22 inches of sand on both sides of the fence. A planting schedule of European beach grass and fertilization has been set up beginning in October 1978 and continuing for three years. The goal of this cooperative project with the Soil Conservation Service of the Department of Agriculture is to halt the eastward movement of the dune towards Highway 101.

A second dune stabilization project is under way in the Ocean Shores area. Here, at the southern end of the beach, on the northern side of the North Jetty, limited accretion and vertical dune growth have occurred. The sand is now as high as the North Jetty, and northerly winds pick the sand up and carry it in a southerly direction into the channel entrance.

In order to stabilize this area, a beach grass planting project has been implemented by the City of Ocean Shores and the Soil Conservation Section of the U.S. Department of Agriculture. European beach grass was planted in approximately two acres of unstable, wind-driven sand just north of the North Jetty in the Fall of 1976. Fertilizers were applied at the rate of 250 pounds of 16-16-16 (P-N-K) per acre along the foredune for a distance of approximately 1½ miles. In addition, two 500-foot "snow" fences were installed in the summer of 1976 to aid in the deposition of sand to rebuild the primary dune which was washed away during the destruction of the North Jetty.

Some of the planted grass apparently did not have sufficient time to get rooted, since winter storms removed many of the plantings. However, some of the grass plantings did stabilize blowout areas and areas of disturbed dune vegetation. Although the "snow" fences were accreting sand effectively at about a rate of two inches per month, winter storms and high tides took out the fences in November 1976. A second group of fences established further inland in the same area were destroyed by a storm and high tides in March 1977. The fence program has been abandoned, but plantings of European beach grass and dune fertilization is planned for 1978 and 1979, since these plants are capable of surviving under marginal conditions.

Man-induced Dune Modification

Recreation Vehicles

A considerable recreational vehicle problem exists in the dunes in the area from Oyehut to Ocean City. The dunes in the city of Ocean Shores have been declared Natural Areas, and use by motorcycles, horses, and four-wheel drive vehicles is prohibited. By comparison of aerial photographs, one can see the multiplicity of trails in the area north of Ocean Shores where such a prohibition is not enforced, while there is less evidence of such features through the dunes in the Ocean Shores Natural Areas. Police Chief Gale Stokes of Ocean Shores stated that the initial prohibition of driving on the beach and dunes south of the Oyehut access road caused the primary dune to increase in height as much as five feet in one year in some areas where four-wheel drive vehicles were previously destroying the dune.

The use of recreational vehicles in and through the dunes seems to be the most vexing problem caused by man along Washington beaches. The drivers of dune buggies and four-wheel drive vehicles, the motorcyclists, and the horseback riders do not feel compelled to use existing access roads. If this type of use were infrequent, the dune vegetation would recover and dune stability would be maintained. However, two areas along the Washington beaches, one between Klipsan Road and Cranberry Road at Long Beach and the other in the dunes that are part of Ocean Shores, demonstrate the destructive impact of increasing numbers of vehicles driving through the dunes.

Access Roads

Various local officials, such as county commissioners, county planners, and various city officials were unanimous in saying there are adequate access roads, with one exception. Grays Harbor County Commissioner Youmans expressed a need for at least one new road near Roosevelt Beach. The roads are expensive to maintain, and even though some support funds are available from state agencies, no one felt more access roads are a solution to the traffic jams, especially during clam tides. Reducing the number of clam diggers by some management technique of delaying the exit of some of the people from the beach were mentioned as possible ways to improve this bottleneck situation.

Various local officials and citizens were unanimous in their desire to be able to drive on the beaches and to park cars on the beaches during clam digging. The alternative of not driving on the beaches during a clam tide and providing parking in the dune area was not accepted as a realistic solution by people interviewed. According to these people, even during closed clam seasons, driving restrictions would in effect create private beaches between approach roads, since many people will not walk very far away from the roads.

It was the feeling that if adequate parking for clam diggers were to be provided, hundreds of acres of valuable dunes would have to be paved or otherwise altered. The resulting aesthetic and ecological effects of trying to cope with parking cars behind the dunes would cause many new problems that need careful study as to their long-range effects.

Alterations of Primary Dunes

The other major problem in the dune area is the removing of a section of dune by home owners and developers in order to maintain a view of the ocean. Such excavations have been made on the beach near Klipsan as well as at Grayland and the beaches north of Grays Harbor. An opening such as this allows the sand to move through the gap by wind action, and removes protection from winter storm waves. Both of these effects could create some problems for the home owner. First, his home may become a giant sand trap and, second, the home is much more vulnerable to destruction by catastrophic storm waves. Furthermore, this type of opening is used by recreational vehicles for access to the beach, further destroying pioneer vegetation seeking to reestablish and stabilize the sand. Obviously, the lowering of the primary dune should be avoided except at designated access roads.

It is the opinion of several people interviewed that sand dunes and attendant vegetation will "heal" if given the opportunity. However, the increasing popularity of the ocean beach areas for view cabins and recreational vehicles are not conductive to the "healing" process. The inability of various levels of government to adequately cope with the problems associated with the primary dune is frustrating for field personnel, who are apprehensive about the future of the beach environment.

Driftwood Removal

Another impact of man on the sand dune stability is the removal of driftwood and logs from the beach. Driftwood and logs have probably always been removed by man from the beach. However, in recent years this activity has become more efficient with the widespread use of chain saws and four-wheel drive vehicles. People remove the wood before it has a chance to become incorporated into the foredune. The result is that the foredune becomes more vulnerable to erosion by wind and waves.

Sand Removal

Long Beach - Pacific County allows sand removal for both cranberry and construction purposes. All construction sand and any cranberry-use sand over $1,000 value requires both a shoreline management permit and a "job ticket" permit issued by the county. Cranberry-use sand of less than $1,000 requires only the "job ticket" permit. The Master Program allows sand removal only between mean high tide and a line 50 feet west of the vegetation boundary. It does not allow removal below mean high tide or within the foredune.

To the date of this report, seven shoreline management permits and two "job ticket" permits have been issued by the Pacific County Public Works Department for 1978.

The permit system amounts to a license to remove unlimited amounts of sand. It is unknown how much sand is actually being extracted due to the lack of monitoring. During the study a group of trucks were loading sand just south of Cranberry Road at the rate of approximately 40 cubic yards per hour. A large pit had been dug because the loading continued for several days. Observations of the excavation 36 hours after it had been abandoned showed that the depression had been partially filled by wind and tide. In spite of this apparent rapid recovery, in the longer time frame of 20 months, the continuous removal of sand from the same area did seem to affect the growth of the foredune, as indicated by the lack of vertical dune growth shown near Cranberry Road, as seen in Figure 13.

The need for sand is considerable and falls into three main categories: cranberry bog fill, septic tank drain fields, and housing foundation fill. The volume of sand for cranberry bogs is minor compared to the need for construction and drain field use. And the amounts needed for the latter two uses will probably increase as residential projects continue to increase. Also, new housing must conform to the higher elevation requirements for the National Flood Insurance Program, which will require even more fill than has been used in the past.

The long-term removal of sand appears to be concentrated in limited beach areas near access roads, e.g., Cranberry Road. It would appear prudent to spread the removal out over a longer stretch of beach. By a system of rotating areas open to sand removal on a quarterly or semi-annual basis, the effect on the dunes would be mitigated.

Significant volumes of sand are used at Long Beach to maintain beach approach roads, for instance to form shoulders five to six feet high. These shoulders protect the dirt-gravel fill that is periodically put on the approach road.

Grayland - Grays Harbor County allows sand removal for cranberries only if a variance is granted. A shoreline management permit is required where project value is over $1,000. The Grays Harbor County Master Program limits sand removal to the "upper beach" but does not allow removal from the primary dune. It should be noted that the North Cove area is in Pacific County and is controlled by Pacific County Regulations.

During recent years no permits have been filed with Grays Harbor County to remove sand from the beaches, since cranberry growers are assumed to be under the $1,000 sand-value limit, and other people are assumed to get sand elsewhere. The non-cranberry users are able to purchase other sand fill from private ownership (Hindman property) in the approximately 40-foot high sand dune in the North Cove area.

The city of Westport has adopted the regulations of the National Flood Insurance Program.

Illegal beach sand removal at Twin Harbors-Grayland does occur in the vicinity of County Line Road, and to a lesser degree further north. The impact of this removal on the dunes is unknown. The cranberry growers do not appear to take enough sand to have a detectable effect on the dunes. If steel marker posts were installed along this beach, more objective measurements could be carried on over a number of years.

North Beach - This area is also part of Grays Harbor County, and therefore sand is only permitted to be removed for cranberry culture. The city of Ocean Shores, in its access road maintenance program, makes limited amounts of sand available to contractors filling home sites within city limits. There are only a few cranberry bogs in the area north of Grays Harbor, so that demand for sand for bogs is minimal.

Ocean Shores has adopted the regulations of the National Flood Insurance Program. City homes are now required to have their foundation footings set 18 inches above the roadway elevation. This requires a considerable amount of fill over the years although much of it could come from the dirt-gravel pit in the Hogans Corner area. Other portions of the beach are governed by county regulation, and in new construction by the National Flood Insurance Program regulations.

RCW 43.51.685 gives the Washington State Parks and Recreation Commission jurisdiction of certain accreted lands including both public and private properties in the Seashore Conservation area along the Pacific Ocean and also provides in part as follows: "Sale of sand from accretions shall be made to supply the needs of cranberry growers for cranberry bogs in the vicinity and shall not be prohibited if found by the state Parks and Recreation Commission to be reasonable, and not generally harmful or destructive to the character of the lands...." "Provided further, that the state Parks and Recreation Commission may grant leases and permits for the removal of sands for construction purpose from any lands within the Washington State Seashore Conservation area."

The present position of the state Parks and Recreational Commission is to allow the counties to administer the sand removal program. However, the commission has several proposals related to sand removal which were outlined in their June 19, 1978, meeting under Agenda Item E-2; Ocean Beaches; Pacific and Grays Harbor Counties; Sand Permits, Blanket Authority.

The approval of the Shoreline Master Program for Pacific County and Grays Harbor County by the Washington Department of Ecology further complicates the management jurisdiction of sand removal from the beach.

Resolution of the diverse and conflicting authority over who controls beach sand removal needs is important. Increasing demand for beach sand can be managed if some guidelines and monitoring are implemented.

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APPENDIX A

MAP SOURCES

MAP SOURCES

Shoreline Date	Source
Long Beach	
1871-73	U.S. C. & G. S. T-Sheets: 1341a, 1341b, 1293
1926	U.S. C. & G. S. T-Sheets: 4251, 4252
1936	U.S. Army Tactical Mapping
1948	Washington State Department of Natural Resources Surveys
1955	Aerial Photography
1977	Aerial Photography
Grayland	
1926	U.S. C. & G. S. H-Sheets 4620, 4621
1936	U.S. Army Tactical Mapping
1952	Aerial Photography
1955	Aerial Photography
1977	Aerial Photography
North Beach	
1887	U.S. C. & G. S. T-Sheets 1701, 1781, 1782
1913	U.S. G. S. Ocosta Quad
1926	U.S. C. & G. S. H-Sheets 4710, 4715
1952	Aerial Photography
1955	U.S. G. S. Quadrangles
1977	Aerial Photography

APPENDIX B

SHORELINE MEASUREMENTS
ACCRETION-EROSION RATES
DEPARTMENT OF FISHERIES DATA

LONG BEACH

Distance from 124° 04' (feet)

Latitude (minutes)	Year 1871-73	1926	1936	1948	1955	1977
37'	-920	-340	300			
36'	-540	160	500	750	650	400
35'	420	340	1080	1170	1200	950
34'	1290	1090	1450	1620	1900	1600
33'	2040	1500	1600	1870	2000	1900
32'	2500	1750	2150	2180	2300	2050
31'	2750	2130	2300	2340	2600	2100
30'	2930	2340	2500	2550	2600	2300
29'	3170	2500	2700	2640	2700	2500
28'	3170	2590	2800	2780	2650	2500
27'	3250	2750	3000	2800	2650	2450
26'	3275	2840	3000	2760	2700	2300
25'	3330	2920	2900	2740	2600	2250
24'	3360	2920	2800	2680	2400	1900
23'	3250	2840	2900	2180	2200	1650
22'	3225	2670	2600	2190	2000	1400
21'	3000	2390	2300	1770	1400	1000
20'	2500	2000	1600	1140	800	400
19'	1790	1170	950	400	200	-300

Positive distances indicate the shoreline lies east of 124° 04'.
Negative distances indicate the shoreline lies west of 124° 04'.

GRAYLAND

Distance from 124° 07' (feet)

Latitude (minutes)	Year	1926	1936	1952-55*	1977
54'		-3000	-4700		
53'		-2000	-1700		-2250
52'		- 200	00	200	- 100
51		1400	1400	1650	1400
50'		2700	2500	2900	2700
49'		3900	3650	3900	3750
48'		4700	4600	4800	4500
47'		5400	5400	*5200	5100
46'		5750	5750	*5450	5350
45'		6100	5500	*5400	5250
44'		6100	5900	--	--
43'		7200	--	--	--

*denotes 1955 photographs

Positive distances indicate the shoreline lies east of 124° 07'.
Negative distances indicate the shoreline lies west of 124° 07'.

NORTH BEACH

Distance from 124° 10' (feet)

Latitude (minutes)	Year	1887	1926	1936	1952-55*	1977
9'		-5580	-5375	-5500		
8'		-3900	-3830	-4100		
7'		-2660	-2870	-3000		
6'		-2100	-1830	-2500	-2300	-2650
5'		-1330	-1080	-1550	-1500	-1900
4'		- 580	- 420	- 700	-1100	-1500
3'		00	00	- 250	- 650	-1050
2'		+ 540	+ 420	+ 100	- 400	- 900
1'		+ 900	+ 670	+ 300	- 50	- 750
0'		+1400	+ 580	+ 300	-*300	- 900
59'		+2100	+ 540	+ 400	-*300	- 950
58'		+3000	+ 375	+ 350	-*600	-1200

*denotes 1955 photographs

Positive distances indicate the shoreline lies east of 124° 10'.
Negative distances indicate the shoreline lies west of 124° 10'.

LONG BEACH

Annual Accretion-Erosion Rates (feet/year)

Latitude (minutes) / Year	1872-1926	1926-1936	1936-1948	1948-1955	1955-1977	1926-1955
36'	-12.9	-34	- 2.1	14.2	11.36	-17
35'	1.4	-74	- 7.5	- 4.2	11.36	-30
34'	3.7	-36	-18.3	-40.0	13.6	-28
33'	10.0	-10	-22.5	-18.5	4.5	-17
32'	13.8	-40	- 2.5	-17.0	11.3	-19
31'	11.5	-17	- 3.3	-37.0	22.7	-16.2
30'	10.9	-16	- 4.0	- 7.1	13.6	- 9
29'	12.4	-20	- 5.0	- 8.5	9.0	- 7
28'	10.7	-21	1.6	-18.5	6.8	- 2
27'	9.2	-25	17.0	-21.4	9.0	3.4
26'	8.0	-16	20.0	- 8.5	18.0	5
25'	7.6	2	13.0	-20.0	15.9	11
24'	8.1	12	10.0	-40.0	22.7	17
23'	7.6	- 6	60.0	- 2.8	25.0	22
22'	10.3	7	34.0	27.0	27.0	23
21'	12.2	4	44.0	53.0	18.0	32
20'	9.2	40	38.0	48.0	18.0	41
19'	11.5	22	45.0	28.0	27.7	33

Negative rates indicate erosion.

Positive rates indicate accretion.

GRAYLAND

Annual Accretion-Erosion Rates (feet/year)

Latitude (minutes) / Year	1926-1936	1936-1952	1952-1977
54'	-90		
53'	-30		
52'	-20	-12	12
51'	0	- 9	10
50'	20	-25	8
49'	25	-16	6
48'	10	-12	12
47'	0	*10	*4.5
46'	0	*16	*4.5
45'	60	* 5	*6.8
44'	20		

*denotes 1955 photographs

Negative rates indicate erosion.

Positive rates indicate accretion.

NORTH BEACH

Annual Accretion-Erosion Rates (feet/year)

Latitude (minutes)	Year	1887-1926	1926-1952	1952-1977
9'		- 5		
8'		- 2		
7'		- 5		
6'		- 7	18	14
5'		- 6	16	16
4'		- 4	26	18
3'		0	25	16
2'		3	31	20
1'		6	28	28
0'		21	33	27
59'		40	32	31
58'		67	34	27

Negative rates indicate erosion.

Positive rates indicate accretion.

WASHINGTON STATE DEPARTMENT OF FISHERIES

Fall Beach Surveys

Annual changes in the position of the +8.0 foot elevation on the beach as measured from an arbitrary baseline. Fisheries profile designations are in parentheses.

Date	Sunset Beach 47° 13.7' (MP) Distance (feet)	Bluff 47° 11' (CP) Distance (feet)	Copalis 47° 06' (GS) Distance (feet)	Ocean City 47° 04' (M) Distance (feet)	Ocean City 47° 03.5' (XL) Distance (feet)	Oyehut 47° 01' (L) Distance (feet)
1951				550		480
52				560		480
53				540		440
54				540		460
55				580		520
56				590	560	550
57				650	560	590
58				690	680	610
59				700	690	650
60	230	250		680	690	680
61	270	220		750	720	680
62	300	230		670	-	670
63	300	230		740	770	760
64	340	260		800	790	800
65	300	260	690	820	760	870
66	330	240	690	780	870	860
67	-	280	710	800	900	870
68	260	250	730	870	900	930
69	290	260	670	900	890	900
70	300	230	-	930	900	-
71	300	240	680	940	930	890
72	350	290	760	980	1000	1000
73	350	300	750	-	990	970
74	-	280		1000	1050	1000
75	310	300		1020	--	980
76	320	300		1050	1000	1040

WASHINGTON STATE DEPARTMENT OF FISHERIES

Fall Beach Surveys

Annual changes in the position of the +8.0 foot elevation on the beach as measured from an arbitrary baseline. Fisheries profile designations are in parentheses.

Date	Ocean Shores 47° 00' (XK) Distance (feet)	Ocean Shores 46° 59' (K) Distance (feet)	Twin Harbors 46° 50' (I) Distance (feet)	Grayland 46° 49' (XH) Distance (feet)	County Line 46° 47.2' (H) Distance (feet)	Gould Road 46° 45.3' (G) Distance (feet)
1951		450	350		490	590
52		520	330		480	600
53		490	260		440	640
54		550	320		480	630
55		620	300		500	770
56		-	300		530	780
57		730	360		610	840
58	670	800	400	460	620	910
59	680	820	350	470	590	840
60	700	800	-	-	-	-
61	810	860	340	530	650	800
62	-	810	350	500	640	850
63	880	960	400	540	680	1000
64	890	1030	410	520	750	1030
65	930	1100	430	520	750	1140
66	980	1130	370	540	710	1090
67	1000	1090	410	610	690	1070
68	940	1120	380	540	725	840
69	--	1140	390	540	700	890
70	--	--	440	520	740	860
71	1030	1140	-	-	-	830
72	1140	1210	370	570	740	950
73	--	1280	350	550	740	900
74	1170	1220	410	530	700	980
75	1140	1280	400	520	680	1200
76	1190	1320	460	580	780	1300

WASHINGTON STATE DEPARTMENT OF FISHERIES

Fall Beach Surveys

Annual changes in the position of the +8.0 foot elevation on the beach as measured from an arbitrary baseline. Fisheries profile designations are in parentheses.

Date	Leadbetter 46° 37' (E) Distance (feet)	Oysterville 46° 34.6' (D) Distance (feet)	Joe John's Road 46° 31' (XB) Distance (feet)	Ocean Park 46° 28.5' (B) Distance (feet)	Klipsan 46° 27.5' (XA) Distance (feet)
1951	530	360		360	
52	560	350		-	
53	570	340		330	
54	550	410		330	
55	580	460		320	
56	540	460		350	
57	-	490	500	390	400
58	760	500	570	380	440
59	800	540	600	420	490
60	860	640	580	480	460
61	1040	610	600	460	510
62	1100	630	580	450	480
63	1160	690	-	450	500
64	1200	720	620	480	580
65	1140	710	640	510	580
66	--	730	-	530	550
67	1060	720	600	580	620
68	1080	700	640	550	620
69	1010	690	590	570	690
70	960	750	650	570	700
71	970	700	630	570	670
72	--	740	680	620	670
73	770	800	730	710	720
74	930	760	640	660	680
75	1020	700	670	660	650
76	1190	830	760	740	790

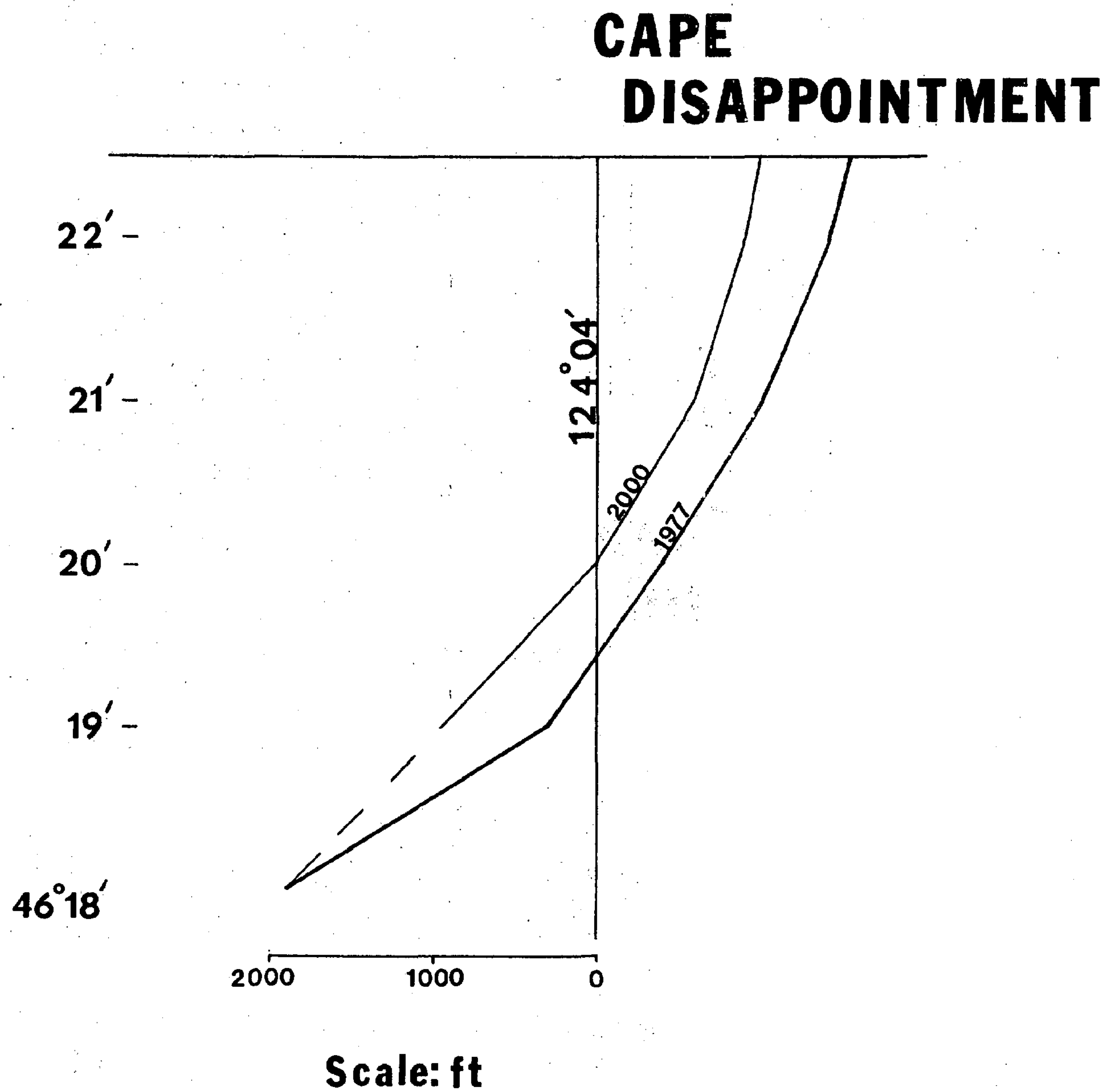
FISHERIES CURVES SLOPES

Linear Regression Analysis produced the following slopes for the Fisheries curves, Figures 3, 5, and 7.

Latitude	Slope
47° 13'	3.3
47° 11'	4.0
47° 04'	21.2
47° 03.5'	23.5
47° 01'	25.0
47° 00'	28.7
46° 59'	34.8
46° 50'	4.4
46° 49'	3.8
46° 47.2'	11.8
46° 45.3'	17.7
46° 37'	21.4
46° 34.6'	18.0
46° 31'	8.1
46° 28.5'	16.1
46° 27.6'	17.1

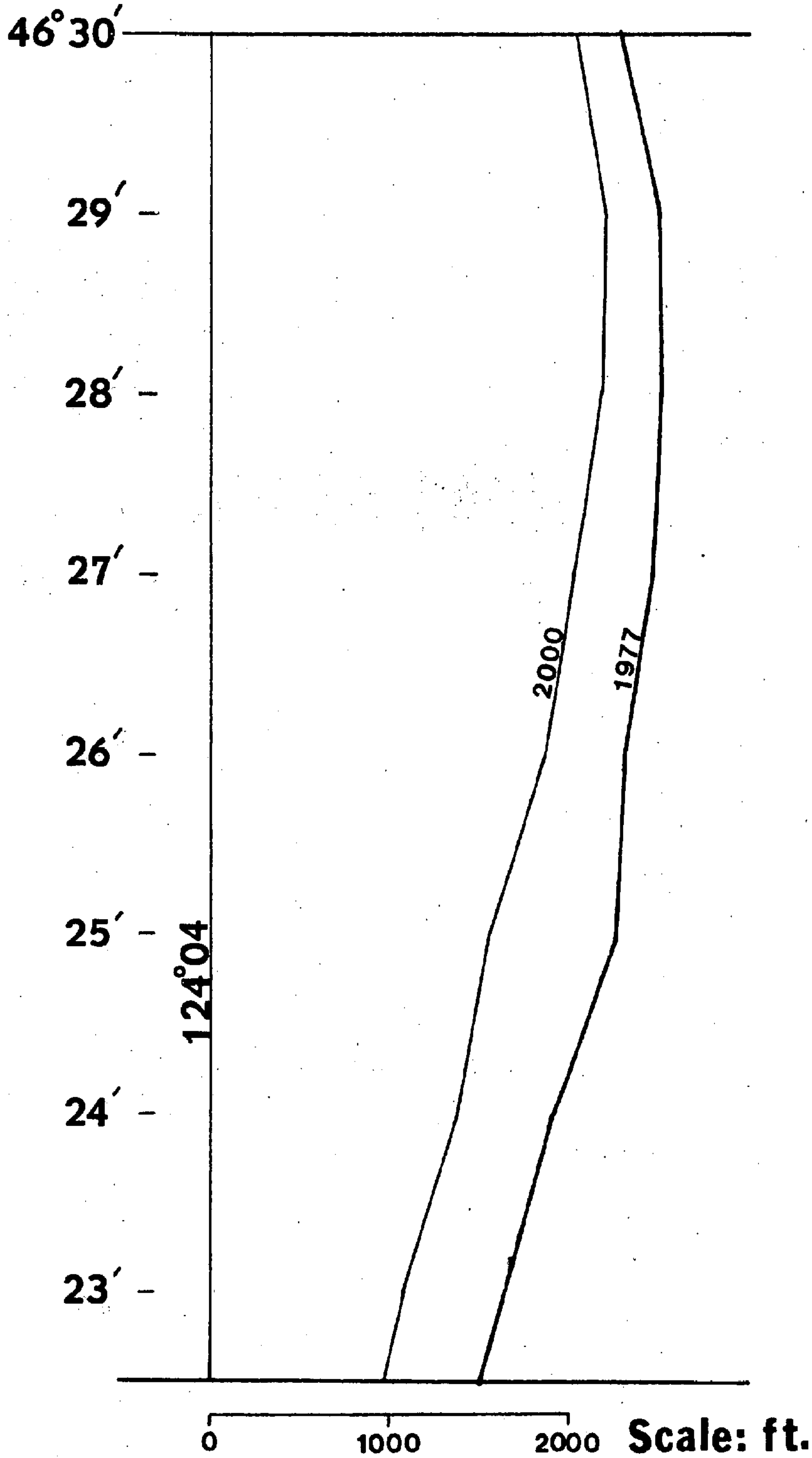
APPENDIX C

YEAR 2000 MAP

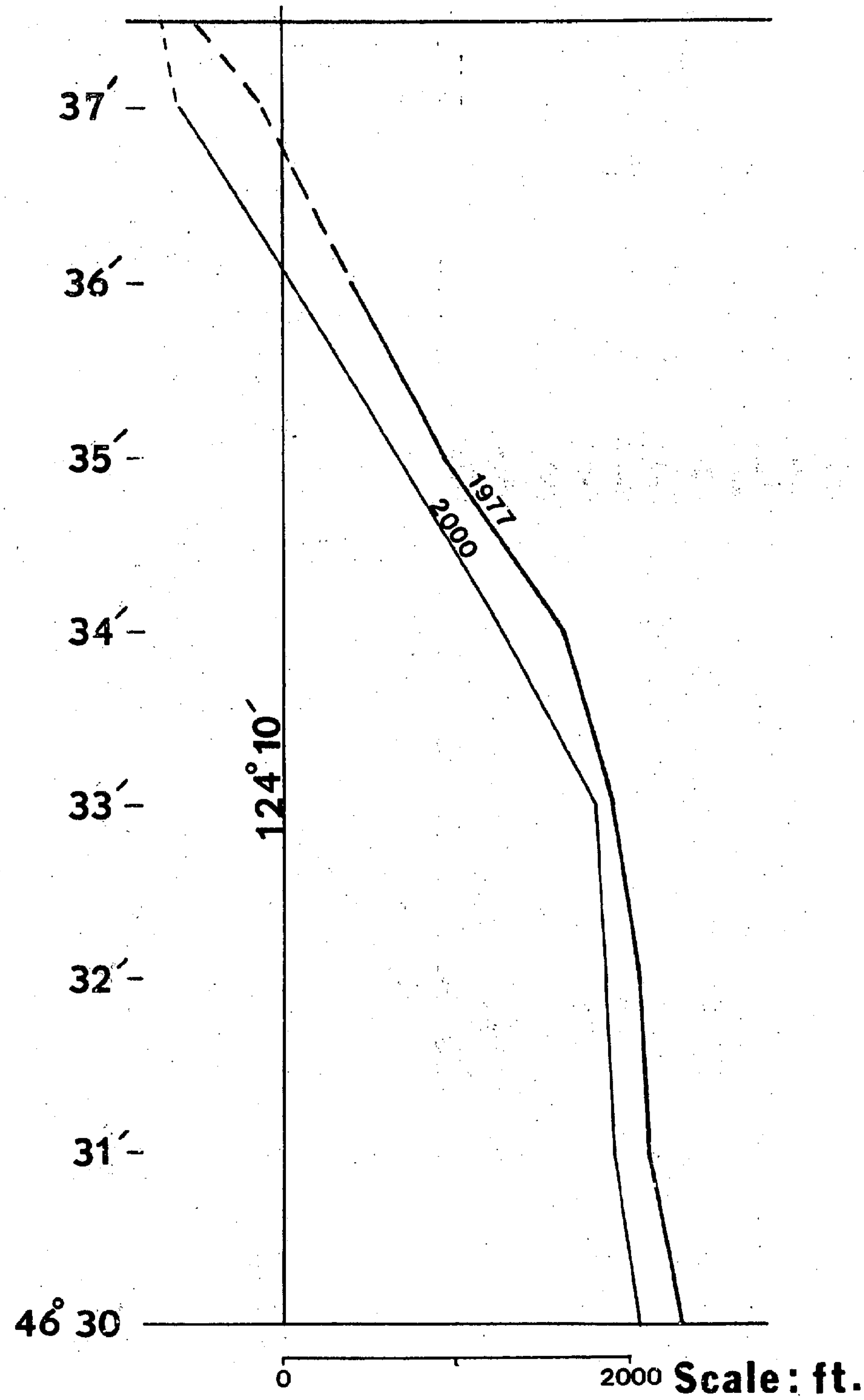


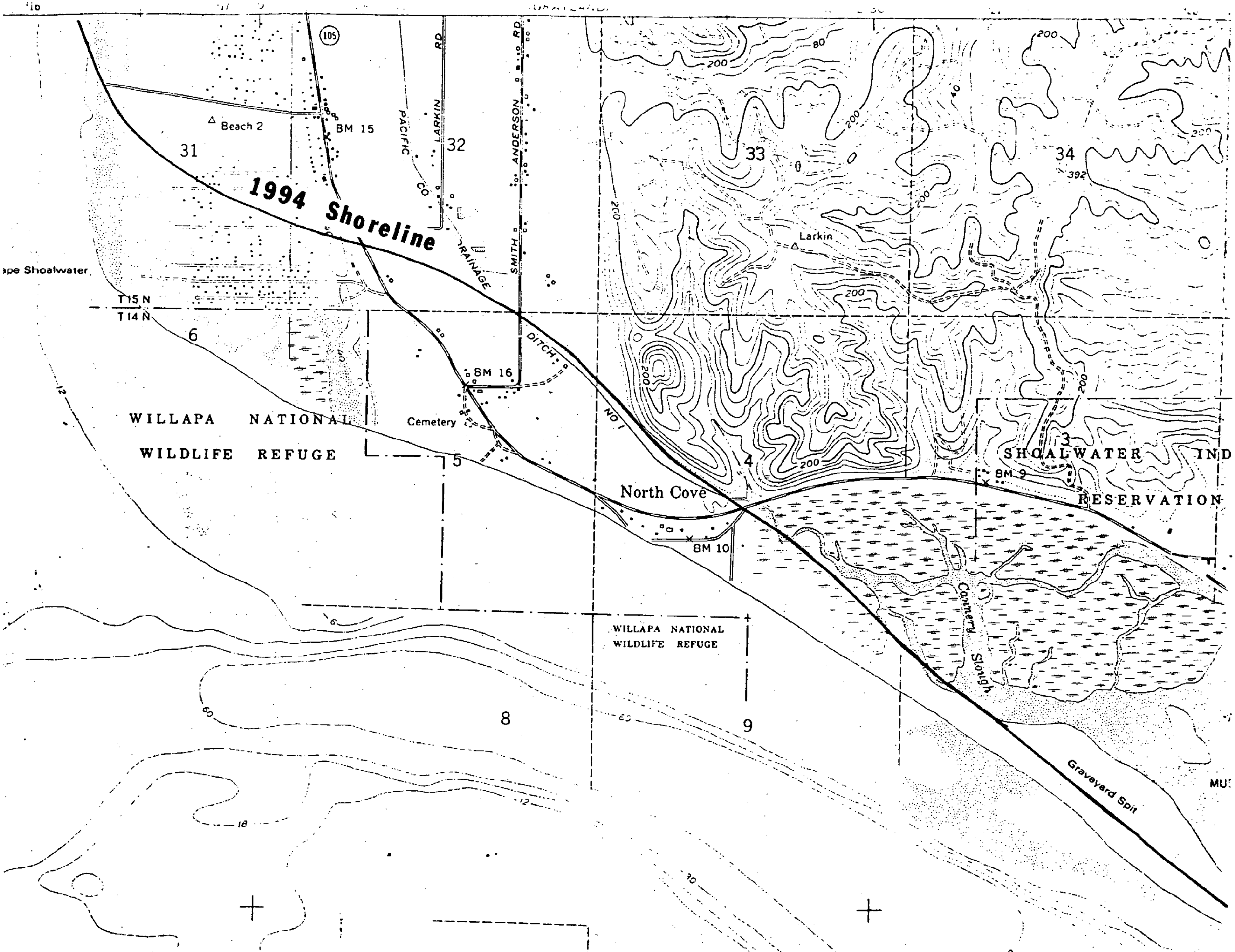
CAPE
DISAPPOINTMENT
22′
21′
20′
19′
46°18′
124°04′
2000
1977
2000
1000
0
Scale: ft

OCEAN PARK

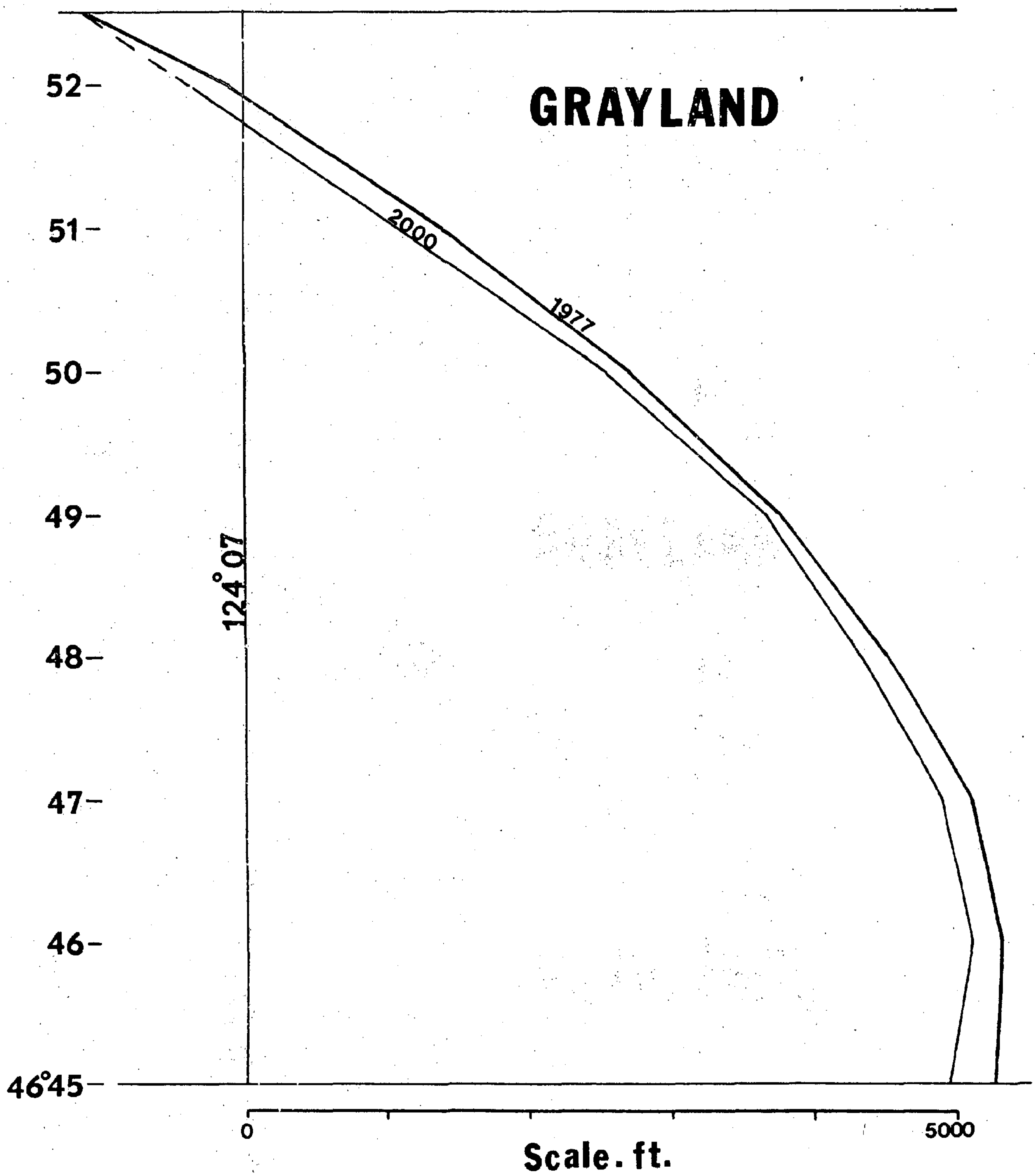


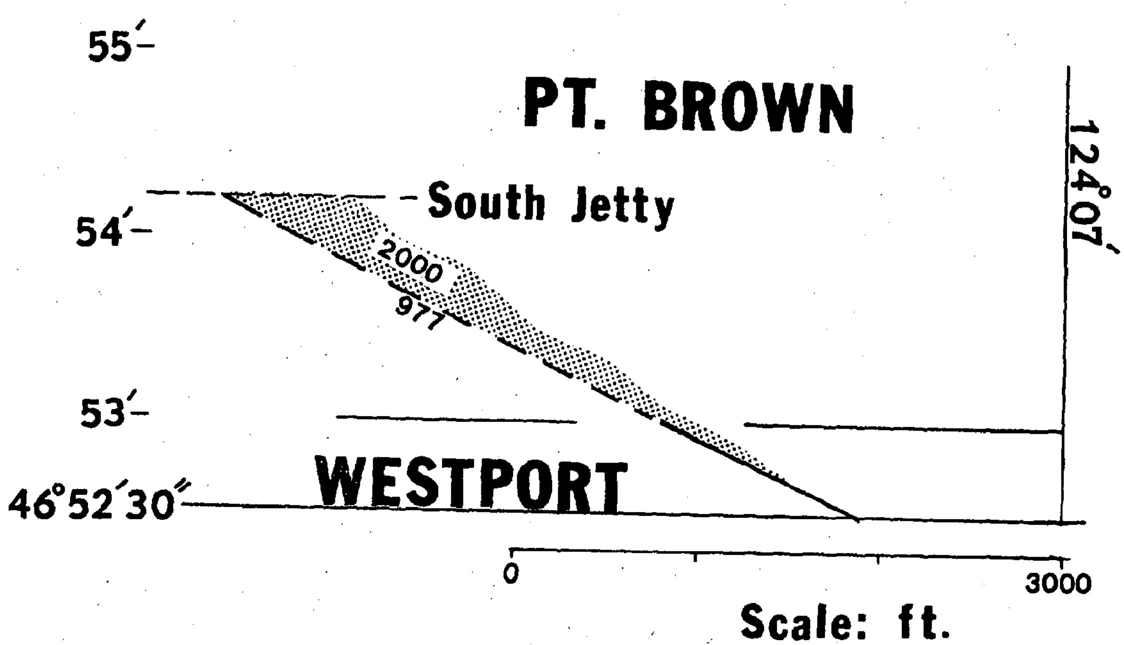
OYSTERVILLE



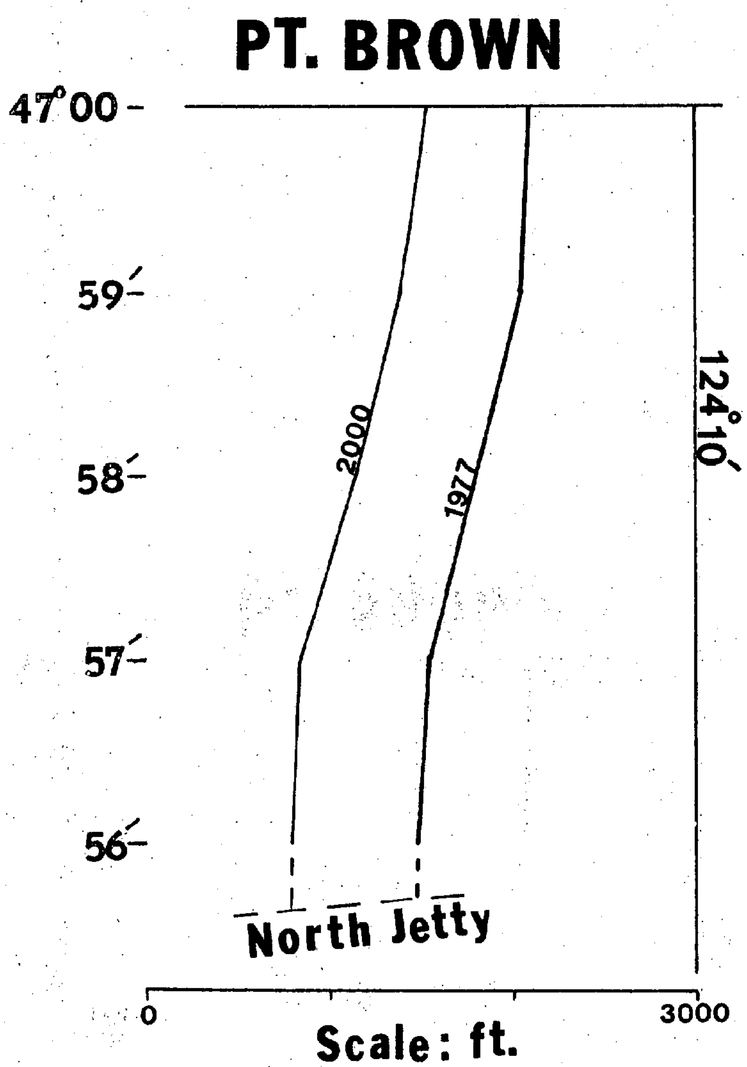


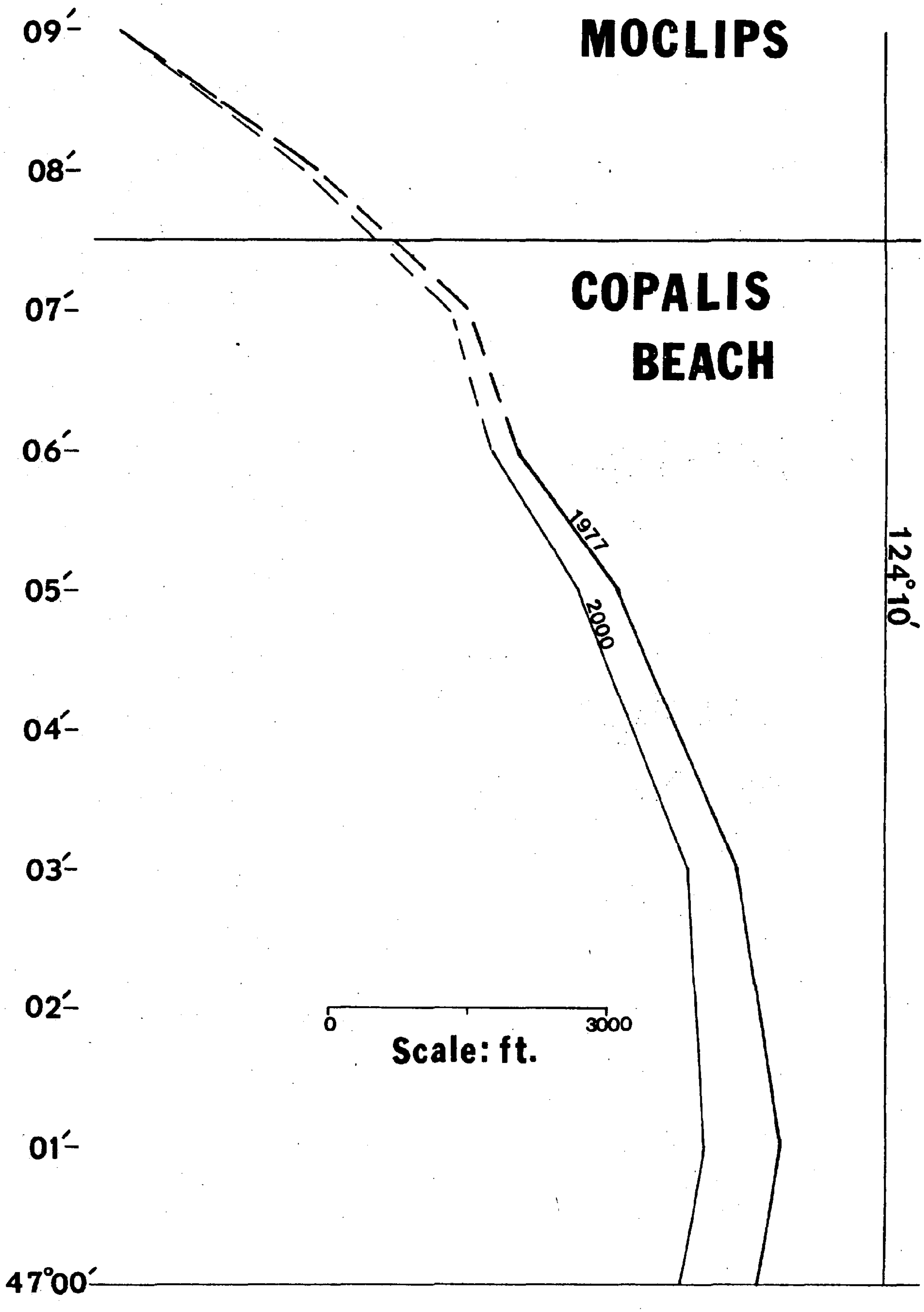
1994 Shoreline
Beach 2
BM 15
BM 16
BM 10
BM 9
PACIFIC CO DRAINAGE DITCH NO 1
LARKIN RD
ANDERSON RD
SMITH
Larkin
Cemetery
North Cove
WILLAPA NATIONAL WILDLIFE REFUGE
SHOALWATER IND RESERVATION
Cannery Slough
Graveyard Spit
T15 N
T14 N
31
32
33
34
3
4
5
6
8
9

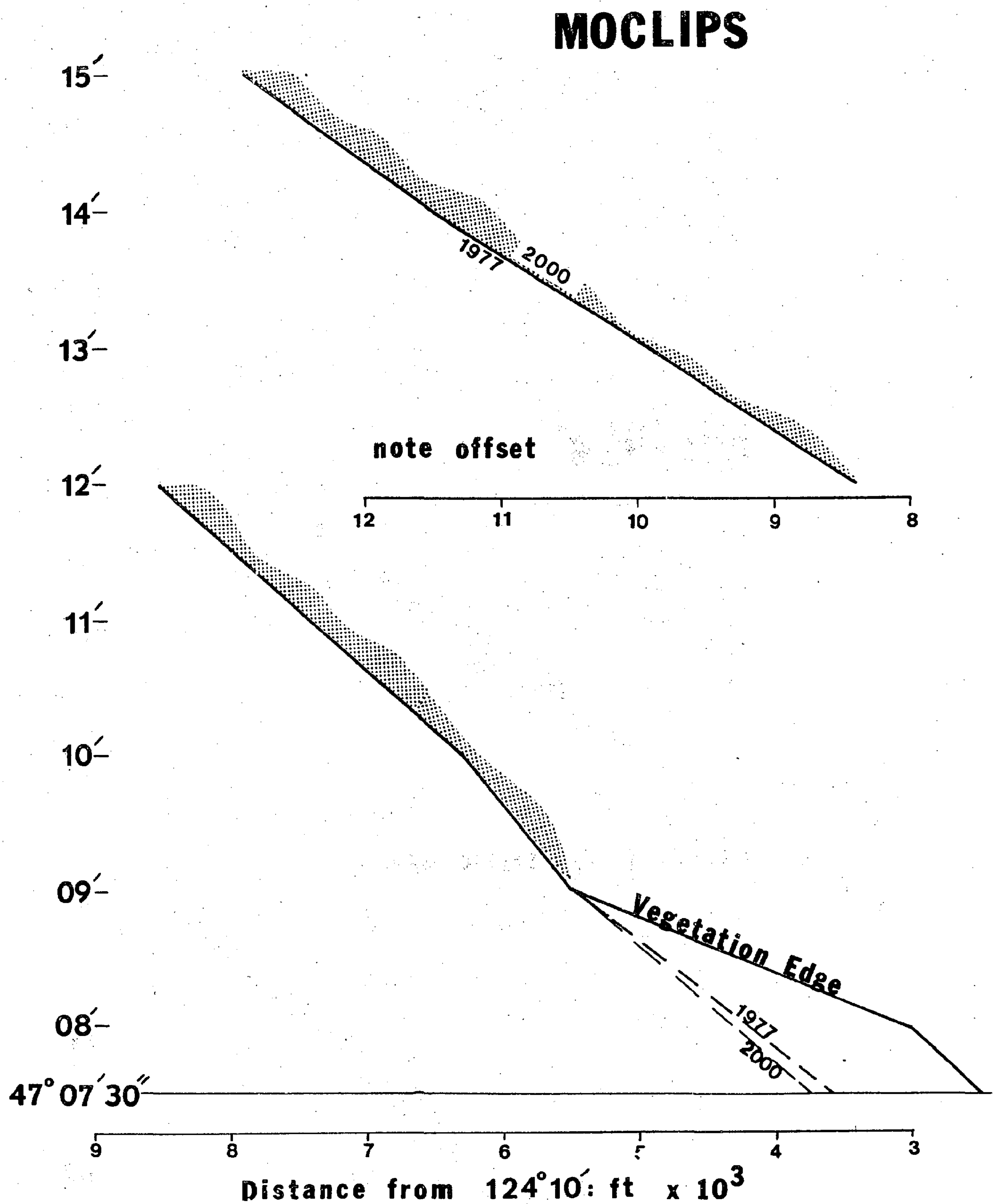

GRAYLAND
2000
1977
52
51
50
49
48
47
46
46°45
124°07
0
5000
Scale. ft.



55'
PT. BROWN
South Jetty
54'
2000
977
53'
124°07'
WESTPORT
46°52'30"
0
3000
Scale: ft.


PT. BROWN
47°00
59'
58'
57'
56'
2000
1977
124°10'
North Jetty
0
3000
Scale: ft.


MOCLIPS
COPALIS
BEACH
09′
08′
07′
06′
05′
04′
03′
02′
01′
47°00′
124°10′
1977
2000
0
3000
Scale: ft.


MOCLIPS
15′
14′
13′
12′
11′
10′
09′
08′
47° 07′ 30″
1977
2000
note offset
12
11
10
9
8
Vegetation Edge
1977
2000
9
8
7
6
5
4
3
Distance from 124° 10′: ft x 10^3

APPENDIX D

PEOPLE INTERVIEWED CONCERNING DUNE MANAGEMENT

LIST OF PEOPLE INTERVIEWED
CONCERNING DUNE MANAGEMENT

Ken Kimura	Planner, Pacific County Public Works Department
Norman Greer	Engineer, Pacific County Public Works Department
Andy Hahn	Engineer, Pacific County Assessors Office
Jerry Rystad	Former Pacific County Assessor
Bill Crossman	Commissioner, Pacific County
Arnold Shotwell	Former member, Pacific County Public Works Department
Stanley Gillies	Former member, Pacific County Planning Commission
Rolland Omar Youmans	Commissioner, Grays Harbor County
John Pearsall	Commissioner, Grays Harbor County
Tom Mark	Planner, Grays Harbor County Planning Commission
Rodger Lackman	Engineer, Grays Harbor County Public Works Department
Judy Rodgers	Resident, Ocean Shores
Bill McDeavitt	Manager, City of Ocean Shores
Beth Jordan	Resident, Ocean Shores
Gale Stokes	Police Chief, City of Ocean Shores
Clifton Todd	Police Chief, Aberdeen & Resident of Ocean Shores
Ed Hammersmith	Washington State Department of Ecology
Mike Kirk	Washington State Department of Ecology
Phil Kauzloric	Washington State Parks & Recreation Commission
Steve Cothern	Ranger, Grayland State Park
Dean Grubb	Manager, Twin Harbor State Park
Clyde Sayce	Biologist, Washington State Department of Fisheries
Dennis Tufts	Biologist, Washington State Department of Fisheries
John Erak	State Representative, Washington State Legislature
Lee Matteson	Resident, Westport

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James B. Phipps and John M. Smith

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9. Performing Organization Name and Address

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Aberdeen, Washington 98520

10. Project/Task/Work Unit No.

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78-080

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Department of Ecology
Olympia, WA 98504

13. Type of Report & Period Covered

14.

15. Supplementary Notes Preparation of this report was financially aided by the National Oceanic and Atmospheric Administration with Section 305 funds under the Coastal Zone Management Act.

16. Abstracts

Approximately 100 years of historical shoreline changes on the coastal beaches of southwestern Washington have been mapped, and the rates of erosion and accretion have been calculated. Indications are that the coastline has been extending seaward since the turn of the century. Notable exceptions occur on the spits abutting Willapa Harbor, and the entire beach north of Copalis Head.

The factors that affect the erosion-accretion rates are considered in light of a sand budget. Projections of recent changes in the shoreline are used to construct a shoreline map for the year 2000.

Man-induced dune modifications are also considered, and dune-stablization methods are explored.

17. Key Words and Document Analysis. 17a. Descriptors

Beach Erosion
Dunes

17b. Identifiers/Open-Ended Terms

Southwest Washington

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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	UNCLASSIFIED	